12TH ANNUAL ALMOND RESEARCH CONFERENCE
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Project No. 84-H6 - Navel Orangeworm, Mite and Insect Research
Modelling Population Dynamics of the Navel Orangeworm in Almonds

Project Leader: Dr. J. K. Oddson (714) 787-5001 or 787-3113
Department of Mathematics
University of California
Riverside CA 92521

Personnel: John Sanderson collaborating with Dr. M. M. Barnes

Objectives: (1) To incorporate an upper temperature threshold for insect development into the navel orangeworm model, and to assess the need for other model revisions which may be suggested by the results of current laboratory and field experiments; (2) To facilitate the evaluation and testing of the completed NOW model by other researchers, which will then lead to release of the model to the almond industry.

Interpretive Summary: Developmental work on the navel orangeworm simulation model is essentially complete and we are now concerned mainly with modifications and fine-tuning as new information and technology become available. Accomplishments during the current project period include:

(1) ***Upper Temperature Thresholds***. Field studies of navel orangeworm population dynamics by Dr. M.M. Barnes and his group at UCR over the last two seasons indicate that orangeworm development during the late spring and the summer is subject to an upper temperature threshold with a vertical cut-off, i.e. suspension of development occurs when temperatures rise beyond a certain point. Such upper temperature thresholds have now been incorporated into the computer simulation model, with interactive software which permits the user to specify or to change their values. Program algorithms have been re-designed and the necessary re-coding and its verification are currently in progress. Expected completion date is December, 1984.

(2) ***Microcomputer Implementations.*** One of this project's goals has always been to make the completed NOW simulation model available on microcomputers, in order to increase the possibility of its general distribution and use. Such an implementation was demonstrated at the 11th Annual Almond Research Conference in December 1983, on an IBM PC running UCSD Pascal. Legal use of the program in this form would have required each end user to purchase the rights to the UCSD p-system. During the last year, however, new microcomputer software has become available. There is now a "Turbo Pascal" compiler which can compile a slight modification of the NOW program down to "native code", freeing the end user from any dependence upon the UCSD p-system and from any purchases other than the disc operating system supplied by the machine vendor. This new version of the NOW program is currently running on the IBM PC and IBM PC compatible machines. It has one disadvantage. Benchmark tests have shown that execution time on the PC can be more than double that on the UCR campus VAX computers. To improve this performance a re-design of the run-time algorithms was undertaken, first on the campus VAX, which resulted in a doubling of the speed on that machine. These speed improvements are now being incorporated into the microcomputer "Turbo" version simultaneously with the upper thresholds feature described above, with completion expected during December, 1984.

(3) ***Planning for Larval Refinements.*** Field experiments over the last summer by John Sanderson, working with Dr. M.M. Barnes, have confirmed earlier indications that orangeworm larval development is accelerated on newcrop almonds during the period after hullsplit and before they have dried. The data, when fully analyzed, are likely to provide new information on inter-instar development as well. At that point appropriate modifications for this pre-harvest period will be incorporated into the simulation model.

The current status of the different machine implementations of the navel orangeworm simulation model is summarized on the following page.

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OW simulation program status:

(1) Version 2.5
  (i) still present on UCR campus VAX and IPM network;
  (ii) "Turbo Pascal" implementation now running on IBM PC;
  (iii) other microcomputer implementations (e.g. APPLE) being explored

(2) Version 2.6 – modification of Version 2.5 which speeds up program execution
  (i) now coded, verified and running on UCR campus VAX

3) Version 3.0 – incorporates upper temperature thresholds into Version 2.6
  (i) final coding and verification in progress on UCR campus VAX; expected completion December, 1984;
  (ii) final coding and verification of a "Turbo Pascal" implementation in progress on IBM PC and IBM PC compatible machines; expected completion December, 1984.
  (iii) IPM network implementation to be upgraded to Version 3.0 after VAX testing; expected Winter, 1985.

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THE NAVEL ORANGEWORM COMPUTER SIMULATION MODEL

by
S. Aggarwal & J.K. Oddson
The Almond Board of California
and
The Regents of The University of California

What is it? - a computer program which simulates the population dynamics and damage potential of a navel orangeworm infestation in an almond orchard under the influence of ambient weather conditions and grower management actions.

How is this done? - by flow-charting records of individual insect cohorts forward through time as they are born, mature, reproduce, and then die. Internal routines make day-degree calculations as needed and dynamically determine insect development paths, mortalities, and fecundity factors, orchard nut loads and damage, and the effects of management actions.

What is its purpose? - to create a qualitative and quantitative tool which can be used to compare the effects of various pest management actions and thus help to formulate an effective navel orangeworm pest management strategy.

What does it require? - data files on orchard temperatures, insect and orchard parameters, an initial population profile or egg-trapping data, and specification of any management activities such as orchard sanitation, sprayings, or harvest. Default temperature and parameter files are automatically loaded but may then be modified or replaced by the user. The other files are designed for complete interactive creation and input.

What does it produce? - numerical output on the state of the orchard on a per acre basis (including a profile of the insect population classified by insect stages and separated into the developmental tracks of Nonpareil, pollenizer, or grounded nuts and the density and per cent infestation of Nonpareil and pollenizer nuts) at season times to be specified by the user. Simulated egg-trapping results may be included. Output is sent to the computer screen during program execution but may also be obtained in hardcopy form if requested.

Special features of the program - it is completely encased in interactive, shepherding software which provides the user considerable flexibility in the selection of model parameters, in the input of initial data, and in the choice of output options. It includes a system of helpfiles, to be accessed from within the program itself. Hardcopy of this information is shown on the following pages.

NOW>HELP

The NOW program provides a computer simulation of the population dynamics of a NAVEL ORANGEWORM infestation in an almond orchard.

All data and instuctions for a simulation run are to be supplied interactively by the user through a sequence of nested " Command line" prompts and questions. Typing 'X' or 'x' at a command level which has the display X(oooo on its Command line will invoke the operation or sub-command option Xoooo.

All references to "time" in the program signify real time on a Julian scale, with units in days and zero denoting the start of the current year. Population figures in the output refer to "per acre of orchard".

* SUB-COMMAND OPTIONS *

H(elp :
Prints this information.

N(ewdata :
Used for manipulating data files of temperatures, orchard and insect parameters, and initial population profiles. It can also be used to prescribe management actions.
N(ewdata has the sub-command options of H(elp, P(arameters, I(nitpop, W(eather, M(anage, and Q(uit .

O(utput :
Used for specifying the type of output desired, through the responses obtained from a sequence of questions.

S(imulate :
Performs the simulation from start time to stop time provided that all necessary variables have been set, either by default or through the Newdata and Output facilities. Data output is written to the screen and/or files during the simulation.
S(imulate has the sub-command options of H(elp, M(anage, R(eset, S(imulate, and Q(uit.

R(eset :
Restarts the program, re-initializing variables to their default values --- except for the files of insect/crop parameters and orchard temperatures, which are left unchanged from what they were in the previous simulation. Of course, these may then be changed again through Newdata if the user so desires.

D(ebug:

This is a debugging aid which permits the user to observe one-by-one the current list of pending time-ordered model events still to be processed by the navel orangeworm program. This option may be removed in the final version.

Q(uit :

Closes all open files and ends the execution of NOW.

NEWDATA >HELP

The purpose of the N(ewdata command level of the NOW program is to provide the user with a simple means for handling the input data required by the model, pertaining to insect/crop parameters, orchard temperatures, initial populations, and management actions.

* SUB-COMMANDS *

H(elp :

Prints this information.

P(arameters :

Allows you to create, display, or load parameter files.
These files contain the insect developmental thermal constants (temperature thresholds, degree-day times), survival rates, and oviposition parameters, along with crop stats on the nonpareil and pollenizer trees within the planting. The maximum larval capacity

P(arameters (cont'd):

of an average nut and the average times of day at which the low and the high temperatures occur in the orchard may also be entered through this command.

W(eather :

Allows you to load temperature datafiles.
These files contain daily low and high temperatures for an orchard for a single year and one must be made available to the NOW program before a simulation can be run. They may be created, changed, displayed, or printed out by means of a separate WEATHER UTILITY program which has been created for that purpose.It may be invoked by executing the separate program WEATHER at the operating system level.

I(nitpop :

Allows you to create, display, or load initial population files.
These files are files of records containing the kind, size, age, and place of the initial cohorts of insects.

M(anage :

Allows you to schedule management activities including spraying, winter sanitation, and harvesting.
A listing of these management actions, both completed and still pending, may be reviewed at any time and printed out at the end

of the simulation.

PARAMETER >HELP

PARAMETERS is a command option of NEWDATA which handles the input data to the model pertaining to insect and crop parameters.

* SUB-COMMAND OPTIONS *

H(elp :
Displays this information.

D(isplay :
Displays the parameters to the screen from a specified data file.

M(ake :
Creates a new parameter data file using the current values as a template.

L(oad :
Loads the parameter variables with the values from the specified file. If an initial population file has already been loaded then a new parameter file cannot be loaded without resetting the simulation.

X(tra :
Allows you to change CAPACITY, the larval nutritional capacity of an average almond nut, and MINPOP, the minimum insect cohort size that the program will bother to track.
The purpose of CAPACITY is to permit implementation of a resource-dependent larval mortality on the insect population; its default value has been set at 6 navel orangeworm larvae.
The purpose of MINPOP is to prevent model processing of cohorts of extremely small size; its default value has been set at 0.1 insects per acre, but simulation results seem to be quite insensitive to this parameter.

Q(uit :
Returns you to the Newdata command level.

WEATHER > HELP

The purpose of the weather option of the command level Newdata is to give you the ability to load different temperature data files. These files contain real numbers representing one year (365 days) of daily low and high temperatures, beginning with January 1st. Indexing proceeds as T0, T1, T2, ..., with the low temperature for a day preceeding the high. Thus T0 is the low value for January 1 and T1 the high, T2 is the low value for January 2 and T3 the high, etc. It is NOT assumed that the low and high temperatures for the day occur 12 hours apart. The year-averaged times of daily lows and highs are parameters in the navel orangeworm model which are specified by the user in a Parameters file.

Temperature files to be used by the NOW program must already exist, in properly formatted form. They may be created (as well as changed, displayed, and printed out) with the use of a separate WEATHER UTILITY program which has been designed for this purpose. It may be invoked by executing the separate program WEATHER at the operating system level.

W(eather (cont'd)

In the W(eather option of Newdata the current temperature file is identified and then you are asked whether or not you wish to replace it with another. If you choose to do so, then the program asks for the new file name and attempts to load the new temperatures. If unsuccessful then this weather option is repeated.

Once a population file has been loaded into the navel orangeworm model you may not change the temperature file without resetting the simulation.

A reply of 'H' or 'h' to a y/n question prints this help message.

INITPOP >HELP

INITPOP is a command option of NEWDATA which handles the input data to the model pertaining to the initial insect population.

* SUB-COMMAND OPTIONS *

H(elp :
Displays this information.

D(isplay :
Displays to the screen the information on the insect cohorts in the initial population, as contained in a specified population data file.

M(ake :
Creates a new initial population data file, under the specified name appended with '.pop'.

M(ake (cont'd):
You are asked to enter either field egg-trapping data or an initial population profile. In the latter case, you are then asked for the Julian time at which the profile was taken and the type, size, fractional age, and nut location of each cohort that you wish to include. Such information may be obtained from winter sampling of orchard mummies.

L(oad :
Loads an insect population into the model from the specified file. You are then asked for the percentage of nonpareil and pollenizer nuts which show some evidence of past or present navel orangeworm damage to either hull or nut at that Julian time. Once a population file has been loaded the weather, parameters, or population files cannot be changed and no new orchard cleanups can be scheduled without resetting the simulation.

Q(uit :
Returns you to the Newdata command level.

MANAGE >HELP

Manage is an option of both the NEWDATA and SIMULATE command levels. It will allow you to model the crop management practices of cleanup, spraying,

and harvesting.
All past and pending management activities will be recorded and printed out on a hardcopy, if hardcopy is requested under the O(utput option of the main NOW command level. Within the MANAGE command level they can also be displayed on the screen.

* COMMAND OPTIONS *

H(elp :
Prints this information.

S(pray :
Used to schedule spraying events.
You choose the type of spray (larvacide or adulticide) and enter the (future) time at which this spraying is to occur.
L(arvacide:
Initial Effect – 15% of existing eggs and 45% of existing larvae less than 6 hours old are killed.
Residual Effect – Newly laid eggs and newly hatched larvae are killed by a percent linearly decreasing from the initial effect to 0 over a period of 21 days.
A(dulticide:
Initial Effect – Affects eggs and larvae as above; in addition 100% of existing adults are killed.
Residual Effect – Affects eggs and larvae as above; in addition newly emerged adults are killed by a percent linearly decreasing from the initial effect to 0 over a period of 21 days.

R(haRvest :
Used to schedule inseason harvesting activities (tree nut removal – usually by shaking, and ground nut removal by sweeping).
You must enter the time of nut removal from the trees, and whether from the N(onpareil or P(ollenizer trees; the number of nuts left per tree; the time of nut removal from the ground; and the percentage of ground nuts which remain.
Harvest events can only be scheduled after the current model time and sweeping can only occur after shaking.
When a shaking is processed in the simulation, a percentage of insects will become ground nut insects equal to the percentage of nuts which fall. Removal of ground nuts will reduce the number of ground nut insects by a percentage equal to the percent of ground nuts removed.

C(leanup :
Used to model the events of orchard sanitation – tree nut removal by shaking or hand–poling, as well as ground nut destruction. Any cleanups to be scheduled must be entered before an initial insect population is loaded into the model.
You choose whether it is to be a P(reseason (before Jan. 1) or F(uture cleanup. Preseason cleanups are performed by the model before simulation begins, and can be scheduled to occur between the

time of last year's harvest and Jan. 1st. Future cleanup events can only be scheduled after the current model time. They are processed during simulation. Ground nut destruction can only occur after tree nut removal.

You must enter the time of nut removal from the trees, how many nuts are left per tree, whether you want ground nut destruction, and, if so, when and what percentage of nuts will remain.

When the event is processed, a percentage of insects will become ground nut insects equal to the percent of nuts which fall. Removal of ground nuts will reduce the number of the insects residing in these nuts by a percentage equal to the percent of nuts removed.

D(isplay :

Used to display a complete list of management activities. You may request to see those management activities which have already been performed and/or those that are pending.

Each of the options S(pray, R(haRvest, C(leanup also has its own display capability.

Q(uit :

Returns you to the NEWDATA or SIMULATE command level.

OUTPUT > HELP

The purpose of the O(utput option of program NOW is to allow the user to select the type and timing of output results. Infestation, crop, and insect statistics are displayed to the screen at model times specified by the user. If hardcopy is requested the same data are sent to a file, to be formatted for printing once the simulation is over. A summary of the simulation conditions -- a description of the orchard temperature file, the insect and orchard parameters used, the initial population profile that was entered, and a listing of simulated management actions -- can be included.

Once the output has been specified it cannot be changed, except by a R(eset from the Simulate or Now command levels.

The following are the questions you will be asked and explanations of possible responses:

Q: Do you need help? y/n
A: y – Prints this information.

O(utput (con't):

Q: Enter E for output after each event;
P to prescribe the output times-->
A: E – Prints degree-day, cohort population and type, and crop information to the screen after the processing of each model event.
P – Provides the same type of information, beginning at a user-selected model time for first output and continuing periodically thereafter at intervals of a user-selected period of time. Initial output time and the output period are obtained interactively from further questions.

Q: Do you want change the basetime (y/n)?
A: y – Asks you for a new basetime for screen degree-day calculations.
n – Leaves the basetime unchanged (default = 0.0).

Q: Do you want to change the threshold (y/n)?
A: y – Asks you for a new threshold for screen degree-day calculations.
n – Leaves the threshold unchanged (default = 55.0 F).

O(utput (con't):

Q: Do you want eggtrapping data (y/n)?
A: y – Further questions you for the time of the first trap emplacement and period between or actual times of subsequent eggtraps. This egg trapping data will be displayed to the screen after simulation, when either reset or quit options are executed.
n – No egg trapping data will be provided.

Q: Do you want a printed copy of the screen output? y/n
A: y – Provides a printed copy of all the screen output. Egg trapping data (if requested) will also be printed. The hardcopy will give a summary of the simulation conditions -- information on the orchard temperature file, the insect input population, and the simulated management activities. It will also include the simulation parameters, provided you respond 'y'(es) to this subsequent question.
After simulation, and before printing begins, you will be asked whether you still want a hardcopy of that particular run.
n – No hardcopy will be provided.

SIMULATE >HELP

SIMULATE is a command option of program NOW. Called from the main command level, it immediately executes its own subcommand S)imulate which is described below. Once called, you will not be able to return to the main command level until the R)eset command is executed.

* COMMAND OPTIONS *

H(elp :
Displays this information.

M(anage :
Allows you to schedule management activities such as orchard sanitation, spraying, and harvesting.

R(eset :
Eggtrapping data, if any, is printed to the screen. The simulation clock is reinitialized to time 0, all events are cleared, open files are closed, and variables are reassigned their initial values. The parameter and temperatures are left unchanged, but the population file, if one was present, has been removed.
If a hardcopy of output was requested you are asked whether you now want it printed.

S(imulate :
S(imulate begins the actual processing of the navel orangeworm discrete event model, tracking the development of the insect and nut populations through the time–ordered sequence of natural life–cycle and crop management events as time advances forward through the season. Numerical results are displayed on the screen at times specified by the user, and are also sent to other files for optional hardcopy output.

S(imulate (con't):

Before simulation can begin, a parameter file and a temperature file must be loaded. An initial population file is optional. The names of these files are displayed on the screen for you.
You will be asked when you wish to pause. Simulation occurs from the current time to this pause time or maximum time, whichever comes first, and then the simulation prompt line reappears.

D(ebug:

This is a debugging aid which permits the user to observe, one-by-one, the model events on the time-ordered current pending list which are still waiting to be processed by the navel orangeworm program. This option may be removed in the final version.

Q(uit :

Prints egg trapping data on the screen, if any. Asks you once again if screen output is to be printed.
All open files are closed and execution of NOW is terminated.