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IMPROVED REGIONAL PREDICTIONS FOR THE SUGARBEET ROOT MAGGOT, *TETANOPS MYOPAEFORMIS*

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Introduction

The sugarbeet root maggot (SBRM), *Tetanops myopaeformis* Roder, is the major insect pest of sugarbeet in the Red River Valley. Although other insect pests may cause more damage than do root maggots in a given year, SBRM are a more consistent threat with at least some area in the sugarbeet growing area of MN and ND suffering damaging populations every year. Occasionally, widespread outbreaks occur wherein much of the Red River Valley suffer high populations of sugarbeet root maggot. Unfortunately, these outbreaks tend to be cyclic and are very difficult to predict.

Larvae (maggots) of SBRM overwinter in the soil at a depth of 6”-10”. Maggots become more active in the spring with warmer temperatures, moving to within 1” - 4” of the surface. SBRM larvae then pupate near the soil surface and become adults, emerging in mid-May. Adult SBRM spend several days in the field into which they emerge before flying into sugarbeet fields to mate, find suitable plants and lay their eggs. It is these immigrating adults that are most easily monitored, making the sticky stake traps a relatively efficient method of monitoring populations. Mating and oviposition occurs until mid-July with larvae hatching in early June when they start feeding on the maturing sugarbeet root. Although there are a number of suitable host plants for SBRM, including native non-crop species, females do show preference for laying eggs on sugarbeet. This indicates that adult female SBRM are capable of evaluating certain environmental factors and/or host characteristics. Larvae stop feeding in September and initiate diapause (a physiological dormancy) in order to overwinter.

The dynamics of an insect’s population are often associated with a number of resources. Climate, available food, and soil type, for example, may influence an insect’s rate of reproduction and survivorship. Because these resources vary spatially, they will have an obvious effect on an insect’s population distribution. Historical patterns of distribution, therefore, can often provide insight into areas that may be at risk during outbreak years. This is especially true with insects that have only one generation per year and whose populations are not influenced by successive generations that build throughout the growing season. Sugarbeet root maggot is such an insect.

For a number of years the grower cooperatives, to assist growers in making management decisions, have conducted seasonal scouting programs for SBRM adults. American Crystal personnel would establish sample sites at between 100-200 locations selected throughout the region based on personal knowledge of previous SBRM activities. Each sample location had three sticky stake traps and was monitored weekly. Unfortunately, these data were never used to estimate regional population dynamics. Because this effort was started before the advent of inexpensive, hand-held Global Positioning System (GPS) receivers, legal descriptions were used to indicate the location of sample sites. In addition to the township, the range, and the section number (TRS) of each sample location, in most years the quarter within each section was also recorded. These data are available for growing years going back to the late 1980’s and represent a database of the seasonal distribution and abundance of SBRM adults that is spatially explicit to a 0.25 mi^2 resolution. Unfortunately, financial exigencies dictated that this effort not be conducted in the growing seasons of 2002 and 2003. The monitoring of SBRM populations is useful to growers. In addition, the historic trap data is useful to researchers studying the regional population dynamics of this insect pest. To continue this effort, a cooperative arrangement was made between the University of Minnesota, North Dakota State University, American Crystal Sugar Co., and the Minnesota Dept. of Agriculture. Unfortunately, available resources precluded using the same number of sites usually monitored by American Crystal in past years. It was decided to investigate the potential for using historical data to target monitoring effort in such a way that fewer locations might still provide a good estimate of seasonal SBRM populations. Trapping data from American Crystal was used to construct a historical database of SBRM abundance and distribution within the Red River Valley. Traps were monitored by personnel from the two universities and the Minnesota Department of Agriculture. To assist in management decisions, weekly maps of adult SBRM abundance and distribution were prepared throughout the growing season and were made available via the WWW.

Methods & Materials

Historical trapping data for the Red River Valley north of Moorhead was obtained from American Crystal Sugar Co. American Crystal typically monitored between 150 and 200 different sample locations each year. Data collected included the location (TRS and quarter section) of each sample site, the number of SBRM adults per stake, and the number of sticky stakes per location. Sites were traditionally sampled with a minimum of three sticky stake traps constructed from a 12" orange garden stake attached to a 1"x1" white, wooden post approximately 18"-24" long. Posts were driven into the ground facing north at the edge sugarbeet fields and the orange garden stakes were covered with Tanglefoot® (The Tanglefoot Co., Grand Rapids, MI). Traps were checked at weekly intervals and adult SBRM stuck to the stakes were counted and removed and the stake recovered with Tanglefoot®. In preparing historical population data, the cumulative mean adult SBRM catch per stake was calculated at each location for the entire sample year. Mean cumulative seasonal catch at each location was used because we were more interested in annual populations than weekly dynamics for this exercise.

The cumulative mean number of adults per location were used to create digital maps representing the annual population density and distribution of SBRM in the Red River Valley. Point maps were created for each year's data in the geographic information system (GIS) ArcGIS 8.2© (ESRI, Redlands, CA). The legal description (TRS) and quarter section information was used to assign a point location to each sample site. The average number of adult SBRM per stake was associated with each point location. The cumulative catch data was tested for spatial autocorrelation using the program *GS+* (Gamma Design Software, Plainwell, MI). Interpolated surfaces estimating the average catch across the region were created for each year by Kriging the average catch per location across the entire region. Although data was available from American Crystal for a number of years we only used data from 6 years (1996 – 2001) to construct historical maps. This was because we felt the population dynamics of SBRM prior to the mid-1990's may be different than are currently being observed. Changes in agronomic practices, insect management and the amount of land in sugarbeet production may have influenced SBRM population dynamics to the point where patterns observed prior to 1995 may not be relevant to today's SBRM abundance and distribution. An interpolated surface estimating the mean adult SBRM regional for the 6 year period was prepared from the annual mean estimates. This 6-year average map was used to target trap locations. All maps, including 2002 population maps, were kriged with a cell size equivalent to $0.25mi^2$, the resolution of the dataset.

At each trap site (55 in 2002 and 65 in 2003), 3 sticky stake traps, facing north, were established beside sugarbeet fields throughout the Red River Valley. Trap locations were recorded using a GPS and were evenly distributed across the Red River Valley to provide a good overall representation of SBRM adult abundance in the region. In addition, because potential outbreaks would likely be noted first in areas that historically have had higher populations, a number of trap locations were concentrated in those areas. Traps were monitored 1-2 times per week. Adult SBRM present on the traps were counted and then removed and the trap re-coated with Tanglefoot®.

Weekly counts were used to prepare interpolated maps that estimated the regional abundance and distribution of adult SBRM. Trap catch data was assessed for spatial autocorrelation. The weekly mean trap catch was mapped at each sample location as a point map and this point map then interpolated using the Kriging module in ArcGIS 8.2. The resulting interpolated map estimated the regional distribution and density of adult SBRM. In addition, interpolated maps were prepared from the weekly cumulative trap catch data.

The accuracy of these estimates was assessed using a validation dataset. In both 2002 and 2003 a subset of sample sites was withheld in calculating the interpolated population estimates and was used to calculate cross validation statistics using SAS. Data from sample and validation sites was log transformed and the mean prediction error and standard error prediction were calculated. A similar exercise was performed for the SBRM catch data from 1997 (a relatively heavy SBRM year) to compare how the accuracy of using approximately half the number of traps to estimate regional populations. A total of 177 sites were sampled by American Crystal field personnel in 1997, a subset of 20 of these sites were randomly selected and interpolated maps estimating adult SBRM population density and distribution were created from the data of the remaining 157 sites. The subset of 20 sites was then used as a validation set for the 1997 interpolated maps.

A website was established (http://nwroc.umn.edu/ent/sbrm2003.html) and interpolated estimates were posted weekly, providing both weekly peak counts and the cumulative seasonal catch. Interpolated maps presented on the website were created with raw population data rather than log-transformed data as it was thought this form of data would be more useful in interpreting current SBRM populations in the field.

Results & Discussion

Variograms indicated that the population distributions of SBRM as recorded by American Crystal trapping efforts were spatially autocorrelated (Fig. 1). In other words, values at closer sample locations tended to be more similar than those from distant sample locations. Data must be spatially autocorrelated for the interpolation techniques used in this study (i.e. kriging) to be valid. The 6-year average map was used to target sample locations for 2002 and 2003 (Fig. 1). Figure 1 indicates the relative mean annual abundance of SBRM through the Red River Valley, consequently, there is no absolute scale provided with the figure. We felt it was more important to illustrate areas that generally had higher populations of SBRM. Sample locations were evenly distributed throughout the Red River Valley with additional sample locations being concentrated in those areas that historically have had high populations of SBRM.

The website facilitated distributing SBRM population data in almost real-time. While this has limited value in larval control in a general year, it may be extremely useful in a heavy maggot year. If numerous adults are recovered, it may be possible to attempt population control through treatment of adults or by applying additional insecticide to the soil post-seeding. To assist in management decisions, both weekly counts (used to estimate the peak emergence period of SBRM adults) and the cumulative catch (used to indicate the seasonal abundance and distribution of SBRM) were presented on the website.

Population data was found to be spatial autocorrelated and interpolated maps estimating adult SBRM population density and distribution were prepared weekly. The weekly population maps illustrated weekly population peaks well (Fig. 2a & 2b). The cumulative seasonal population estimates (Fig. 3a & 3b) showed peak SBRM populations were located in Pembina county, N.D. in both years. It is interesting to note, however, that significantly higher numbers of SBRM adults were recovered in 2003 than in 2002 and the distribution of the population peak was located further south. This moving center of the population peak underscores the dynamic nature of SBRM distribution in the Red River Valley, especially in the northern counties.

The cross validation statistics (Table 1) indicate that neither 2002, with 55 sample locations, or 2003, with 65 locations, were as accurate in estimating SBRM population density and distribution as the 157 trap locations in 1997 would have done had they been used to create real-time interpolated estimates. However, it is also important to note that increasing the trap locations from 55 to 65 had a significant impact on the accuracy of the resulting population estimates.

Cross Validation Statistic	**1997** (157 sample locations)	**2002** (55 sample locations)	**2003** (65 sample locations)
Mean Prediction Error	10.395	59.215	28.047
SE Prediction	10.193	109.44	81.147

Table 1. Cross validation statistics comparing predictive accuracy of 2002 and 2003 interpolated estimates with that of 1997. Generally speaking, the lower the value of any of these statistics, the more accurate are the estimates.

This discussion would not be complete without addressing an important failing of the 2003 sample plan. A validation sample sites located near Castleton, N.D. indicated a significant emergence of adult SBRM that were not reflected in our real-time maps published on the web. This is because data from the validation set was not being used in calculating those real-time maps but was being withheld until after the season for the cross-validation analyses. This underscores the predictive nature of the real-time interpolated maps; they portray the probability of elevated SBRM populations rather than the actual existing populations in the field. As with any other predictive tool, the accuracy of the predictive ability of the model will increase with greater amounts of data. What we have been trying to characterize with this project is the tradeoff between number of sample sites and the accuracy of predictions they provide.
This project indicates it is very possible to create a system of monitoring SBRM populations and preparing real-time regional estimates of populations. Such a system could be extremely useful in periods when the Red River Valley experiences heavy SBRM populations. There are some concerns over areas being under-sampled and areas that have developing SBRM populations that are not reflected in the original sample plan. These can easily be addressed by adding additional sample sites throughout the season.

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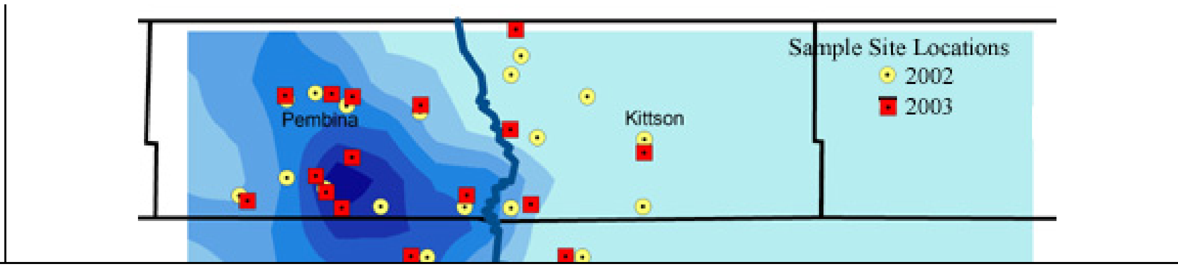
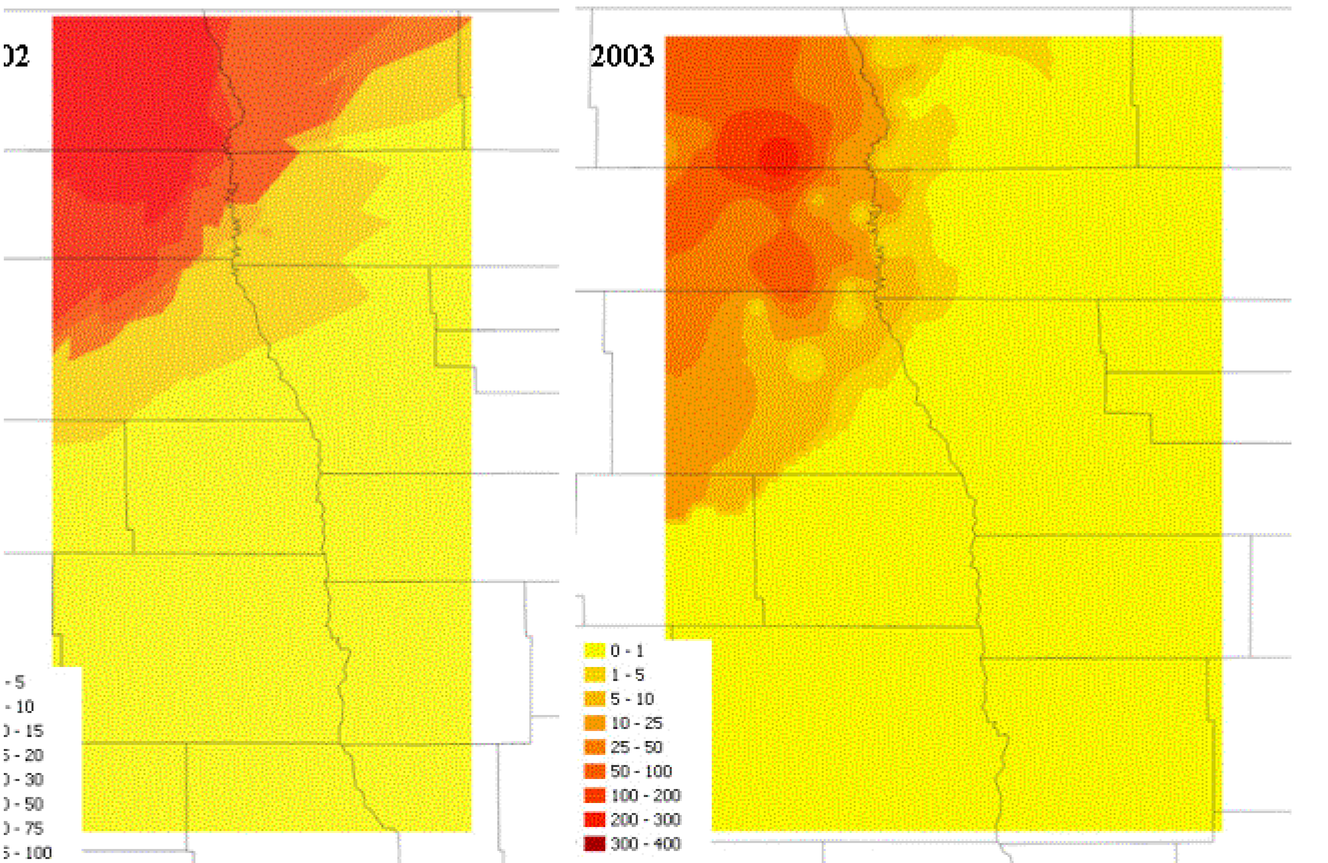




ure 2. Mean peak weekly distribution and abundance of adult sugarbeet root maggot in 2002 (week ending June 20) and 2003 (week ending June 16). Populations in 2003 were higher than in 2002 (note maps are presented on different scales).

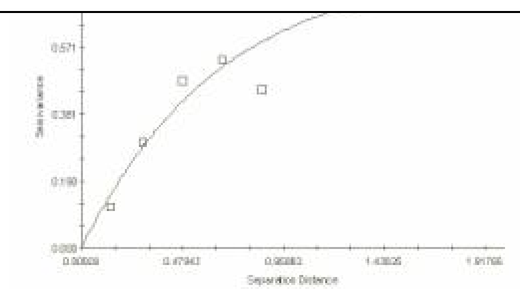
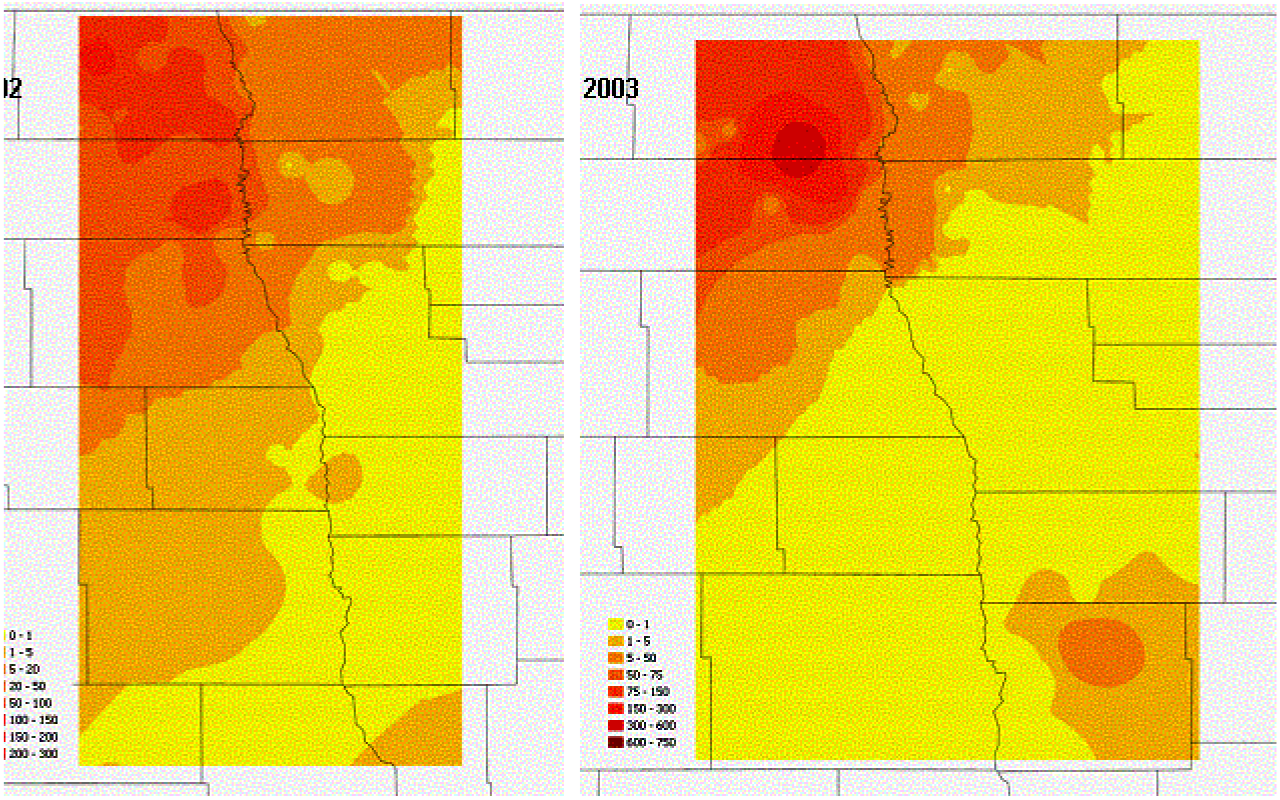


Figure 1. a) Historic pattern of adult sugarbeet root maggot distribution in the Red River valley of Minnesota and North Dakota. Increasingly darker blue areas indicate increasing population. Scale is not presented as it is relative, not absolute. The locations selected for sample site locations in 2002 and 2003 are indicated.

b) Variogram assessing multiple years data for spatial autocorrelation.



ure 3. Cumulative total adult sugarbeet root maggot emergence in the Red River Valley in 2002 and 2003. SBRM adults were more numerous in 2003 (note maps are presented on different scales) and the distribution of the peak population was further to the south.