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FURTHER EXAMINATION OF COTMAN AND GROWER PRODUCTION RECORDS AS A BASIS FOR FARM-WIDE MANAGEMENT OF COTTON INSECTS

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Abstract

COTMAN information and production records associated with insecticide use and yield were organized as a subset of historical records maintained by Wildy Farms, Manila, Arkansas for the period 1997-2002. Resulting descriptive statistics and correlative information define the range of variability in the study data and possible relationships to yield, insecticide use patterns and crop cutout. COTMAN variables associated with longer effective fruiting periods, especially time from planting to cutout, were generally related to higher yields. High fruit retention, greater than 90%, was common across the entire farm. An interesting observation that may deserve more investigation was a suggestion of a negative relationship between retention of 1st position fruit in June and yield. Spatial patterns of insecticide use and densities of insect captures in pheromone traps across Wildy Farms and associated areas of Buffalo Island are presented as an example of future large scale management approaches.

Introduction

Last year, we discussed an initial exploration of a detailed dataset containing COTMAN information, production records and yield for Wildy Farms in Mississippi County, Arkansas (McFall et al. 2003). Our purpose was to illustrate the potential use of detailed COTMAN and production records in forming total farm or area-wide insect management strategies. Our initial work focused on organization and structure of several researchable databases from the information routinely collected and maintained by the farmer and agricultural consultant responsible for insect management decisions. We illustrated the potential application of these data by a descriptive, correlative study of 2002 production records and COTMAN data. Results were spatially linked to individual fields and patterns of significant plant or pest descriptors were plotted across the geo-referenced landscape of the total farm to illustrate important distribution patterns involving multiple fields or regions of the farm. In the 2002 data, we found important linkages in total insecticide use among early season border sprays for boll weevil and tillage patterns. Numbers of sprays made for some pests were negatively or positively linked with numbers of sprays for other pests in the system. For example, fields that received border sprays were more likely to receive spider mite sprays than those that did not receive border sprays. Fields with more sprays for bollworm were also fields with more sprays for fall armyworm and tobacco budworm. Proximity of fields to boll weevil overwintering habitats appeared to be another important influence on insecticide use in 2002.

With the assistance of Cotton Incorporated, we expanded our data management capacity and now have structured databases that will allow us to study many COTMAN and production variables across years of historical information. Some of these databases are very large and beyond the scope of a single research report. The SQUAREMAN dataset alone includes more than 30,000 observations. Yield and spray records have been meticulously maintained for more than a decade, and a detailed dataset of daily pheromone trap captures of bollworm and tobacco budworm has been maintained on the farm and surrounding areas of Buffalo Island for the past 11 years. This paper illustrates our expanding data mining capacity in the study of variables associated with cotton crop development, yield and insect management decisions on Wildy Farms and associated areas of Northeast Arkansas. Examples of information summarized from COTMAN monitoring activities and yield records, insecticide use patterns and production inputs, and pheromone trapping of tobacco budworm are included. Other potential uses of the collective data are emerging as this research matures and our knowledge of the data expands. We concentrated our energies this past year on an examination of records for the six-year period from 1997 to 2002 because of the completeness of the collective dataset for that time frame. More data are available.

In addition to the work on Wildy Farms, we have established a close working relationship with Tillar and Company in Southeast Arkansas. This planting company includes ~10,000 acres of field crops with a concentration of cotton dispersed in a landscape of other crops (corn, soybean, rice), wetland and woodlands. Wildy Farms is almost entirely cotton. As our knowledge of farm-wide information and general data management capacity mature at both locations, we intend to expand the Wildy prototype system of data management to other locations in Arkansas. The COTMAN system of managing and monitoring crop development is a central component of our management approach. We hope to explore different strategic approaches to cotton insect management this coming year and organize the most promising ideas into practical, testable approaches to improved cotton insect management. Efficient within season collection and summary of data remains as a needed aspect of this work.

Methods

Procedures were similar to those described by McFall et al. (2003). Information accumulated from COTMAN mapping procedures and production records for Wildy Farms were summarized for the years 1997-2002. This subset of data was used because of the completeness of COTMAN records and associated insecticide use patterns. The data are not necessarily an accurate description of Wildy Farms as we were interested in paired comparisons of the variables of interest. Incomplete data records were eliminated from our analyses.

COTMAN measurements studied were those listed in Table 3. They were obtained from a database (COTBASE) organized by D. Danforth in the Department of Agricultural Economic and Agribusiness at the University of Arkansas. These records were from original data collected on Wildy Farms. Insecticide use patterns were summarized from a database maintained by D. Wells, the agricultural consultant for Wildy Farms. T. Teague extracted yield records from a large historical database maintained at Wildy Farms.

The collective data were studied by descriptive statistics and simple linear correlation (SYSTAT Version 8.0, 1998). Tables 1-3 report the descriptive statistics associated with each of the variables studied. Tables 4-6 report the correlation coefficients observed when variables were examined relative to 1st pick yield, total yield (1st and 2nd pick combined), total number of insecticide treatments and date of cutout (NAWF-=5).

Using the spatial descriptions of production fields developed by McFall et al. (2003) for Wildy Farms, we examined distribution patterns of the variables studied. Figure 1 shows the spatial distribution of total insecticide sprays, sprays for weevils, sprays for heliothines, and sprays for plant bugs across the landscape of Wildy Farms in Mississippi County, Arkansas.

The farm also collects daily information on pheromone trap captures of bollworm (*Helicoverpa zea*) and tobacco budworm (*Heliothis virescens*) throughout the cotton-growing season. These indexes of insect infestation potential are being studied relative to insecticide use patterns and fruit retention as measured by COTMAN sampling procedures. This is an ongoing effort, and we are just beginning the process. In this paper we illustrate the potential use of these data by spatially depicting the unusual outbreak of tobacco budworm in Mississippi County during the 2002 growing season. Figure 2 contains a series of maps for the Buffalo Island area of Mississippi County that describe average densities of tobacco budworm moths captured at different sample sites during August 2002 and May and June 2003. The associated bar graph shows the relative magnitude of these densities in the northern and southern areas of Buffalo Island for the period June 2001 through August 2003. These densities were the highest tobacco budworm trap captures recorded since records began in June 1993.

Results and Discussion

Total yield averaged 847 lbs lint per acre (Table 1). About 68% of the fields included in the study received at least one insecticide application (Table 2). An average of 3.15 insecticide applications per year was calculated for all fields, including in-furrow applications of aldicarb at planting. About 44% of the fields received at least one application of insecticide for bollworm or tobacco budworm. Pinhead square sprays were typically limited to field borders and were applied to 44% of the fields during the study period. An additional 10% of the fields received an in-season application for boll weevil control.

Table 3 summarizes crop development indices measured by COTMAN. Average date of cutout measured by NAWF=5 was 215 (August 2) over the six year period. This averaged 92.8 days from planting. Plant height ranged from an average of 12.75 inches in June samples to 39.7 inches in August samples. Number of total nodes ranged from 9.15 in June to 18.50 in August. Sympodia averaged 4.19 in June, 9.36 in July, and 13.53 in August. Percent retention of fruit was measured by four different methods (% retention of fruit at the 1st position on the third sympodia from the top of the plant, % retention of the top three fruiting positions on the plant, % retention of squares on 1st positions on the plant, and % retention of all 1st position fruit). In general, fruit retention was high and averaged 94-97% across the different sample methods for June. Retention of 1st position fruit in July was 90%. In August, % retention of 1st position fruit averaged 75%.

Total number of foliar insecticide sprays, number of plant bug sprays, number of thrips sprays, and number of other sprays were positively correlated with yield (Table 4). Number of pinhead square sprays and number of armyworm sprays were negatively correlated with yield. McFall et al. (2003) also found that the number of pinhead square or border sprays was positively correlated with total sprays. Logically, increased number of sprays directed at individual pests was positively correlated with increased total number of sprays. Date of cutout was negatively correlated with number of aphid sprays and positively correlated with number of thrips sprays and number of within season boll weevil sprays. This simple correlation procedure does not differentiate cause and effect. For example, it is unknown if the increased number of aphid sprays associated with an earlier date of cutout was due to the impact of aphids on the plant or an interactive influence related to other plant stresses and altered fruit set. More detailed examination of the data relative to insect scouting and a restricted subset of the data for samples only with aphids could provide more meaningful resolution.

Several of the COTMAN variables were positively related to yield including date of cutout, days from planting to cutout, plant height, height to node ratio, and number of squaring nodes in July and August. Many of these positive correlates seem to describe crop growth patterns that maximize the length of effective fruiting from planting to cutout. Date of planting was negatively correlated with yield. More insecticide use was logically associated with the same variables that suggest a longer growing season. Date of cutout was positively related to days from planting, number of squaring nodes in August and average plant height in August. Date of cutout was negatively correlated with number of squaring nodes, number of nodes and plant height in June and July. Date of cutout was not correlated with date of planting in the dataset, but was strongly correlated with days from planting to cutout. Days from planting to cutout is a more normalized variable that simply measures time from planting to cutout regardless of the calendar date of either event. The lack of a significant correlation between date of planting and date of cutout illustrates the influence of year-to-year variability on efficient crop management. The length of time available for effective fruit set is more critical than that the starting or ending date of effective fruit set.

The different methods of estimating % retention of fruit were examined because they are commonly used in practical crop management decisions. Interestingly, % retention of 1st position fruit was negatively correlated with yield. This negative correlation was only marginally significant ($P<0.05$) but the trend for the effect was evident in a broader examination of the data. Percent retention of fruit measured by the other three methods (% retention of 1st position fruit on the 3rd sympodia from the top of the plant, % retention of the top 3 positions, and % retention of squares) in July and August were positively correlated with yield, but not correlated with yield in June samples. Also, the presence of a negative correlation between numbers of insecticide treatments and % retention of 1st position fruit in June suggests that the measurement of % retention of 1st positions in June is associated with a major crop response. This observation is worthy of additional attention as it suggests that one could invest too much in resources to maintain high fruit retention during June, at least within the scope of variability examined in this exploratory study. More empirical work is needed and conclusions about cause and effect are not warranted.

The overall general patterns of insecticide use across Wildy Farms are illustrated in Figure 1. Patterns for total sprays seemed to be spatially associated with those for boll weevil. In this illustration, boll weevil sprays included pinhead square treatments and within season boll weevil sprays. The different color patters were arbitrarily assigned. The red patterns were generally associated with fields receiving twice the number of sprays received by fields with green patterns. Those with yellow patterns were intermediate in number of sprays. More sprays seem to be common in the northwestern regions of the farm.

Figure 2 shows a spatial pattern of tobacco budworm trap captures during August 2002 and subsequent trap captures in May and June 2003. This is of special interest since tobacco budworm is not a consistent pest problem in this region of Arkansas. The database for this information includes trap capture records back to the 1993 growing season. Trap captures during August 2002 were the highest recorded. Although no direct experimental evidence exists, there is some speculation that the higher densities of tobacco budworm in the more northern areas of Buffalo Island were associated with the initiation of area wide applications of malathion for fall diapause control of boll weevil (*Anthonomus grandis grandis*) in surrounding ridge areas and southern Missouri. If this peak capture was the result of a colonization effect from populations originating in border areas, it may illustrate the lack of suitable hosts or environment to sustain a reproducing population of tobacco budworm on Buffalo Island. An unusually high May 2003 population, perhaps indicating successful overwintering of the pest in the Mississippi County area, followed the historic high August 2002 population. Interestingly, the population dramatically declined from May to June 2003, perhaps indicating the lack of suitable hosts for population increase. As with the correlation studies, this is not solid empirical data and more research is needed to understand the ecology and biology of tobacco budworm in Mississippi County. Fall diapause treatments for boll weevil were initiated in the area of Buffalo Island during 2004. It will be interesting to see if populations of tobacco budworm are detected in the area in spring 2004. Populations in August 2003 had returned to the lower densities commonly observed in the area. It is possible that the high densities in August 2002 were not related to sprays in surrounding areas.

Summary

Our correlative studies illustrate a potential use of historical information in formulating new management approaches. The data mining aspect of this work is not intended as explanatory experiments. Wildy (2000) indicated several advantages of

COTMAN information in the day-to-day management of his crop including: (a) an ability to monitor crop progress field by field throughout the year, (b) a means of determining fruit retention on any given field, (c) confidence in knowing that the crop is on target at any particular time during the growing season, (d) a savings of $9.40 per acre in insecticide costs, and (e) a ranking of fields relative to crop maturity and scheduled harvest operations. Perhaps the accumulation of these data across multiple seasons will allow additional strategic considerations of crop management inputs. Our exploratory work suggests that the impact of early season fruit retention and the costs of maintaining high fruit retention during the early season deserve further study and investigation. This is a complicated question as it relates to strategies for the entire farming operation and scheduling of management actions across many individual production units. This farm level management impact and the potential use of multiple COTMAN descriptors across many fields or many production zones within a given field deserve more conceptual consideration. Our preliminary work suggests that crop profile information provided by routine COTMAN data collection will be an essential component of larger scale strategic considerations.

Wildy (2000) estimated that the cost of running the COTMAN program on his farm was approximately $2.33 per acre. Current budgets for cotton production in Arkansas (Bryant et al. 2004) estimate direct expenses of insect management (custom sprays, insecticides, technology fees, and insect scouting) well in excess of $100 per acre. Insect scouting is estimated at $8.00 per acre in these budgets. Williams (2004) estimated total control costs for cotton insects in Arkansas during 2003 at $129.42 per acre. This included an estimated $6.89 in insect scouting costs. Given these rising costs of cotton insect control and the strong investment in insecticides and technology fees, a greater investment in management capacity and quality information seems prudent. Insect scouting was less than 7% of the total costs of cotton insect control in Arkansas last year (Williams 2004). Long-term investments in these information sources may be a foundation for innovative site-specific management options that operate on non-traditional management scales ranging from within field row to row resolution to large unit strategic decisions across entire farms or farming communities. Regardless of the scale of the management unit, site-specific information will be a critical aspect of efficient management. Estimates of probabilities of damage and infestation will likely become aspects of future management systems. These data can only come from multiple year records like those of Wildy Farms.

Acknowledgements

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Table 1. Descriptive statistics associated with yield (lb lint/acre) in subset of Wildy Farms production records, 1997-2002.

Yield Variable	n	Mean	Std. Error	Minimum	Maximum
Avg Per Field 1st Pick	485	805.69	8.34	162.30	1324.80
Avg.Per Field 2nd Pick	385	51.86	1.09	16.60	166.70
Avg. Total Per Field	483	847.16	8.56	162.30	1399.60

Some fields in the data set were harvested only one time.

Table 2. Descriptive statistics associated with insecticide use (average numbers of treatments per field) in subset of Wildy Farms production records, 1997-2002.

Insecticide Treatment	n	Mean	Standard Error	Minimum	Maximum	% of Fields Treated
Temik Applications	546	0.70	0.02	0.00	2.00	67.9
Aphid Sprays	546	0.16	0.02	0.00	2.00	15.3
Armyworm Sprays	546	0.07	0.01	0.00	2.00	6.4
Plant Bug Sprays	546	0.49	0.03	0.00	4.00	6.4
Spider Mite Sprays	546	0.12	0.02	0.00	2.00	8.9
Thrips Sprays	546	0.50	0.03	0.00	3.00	31.6
Pinhead Square Sprays	546	0.11	0.01	0.00	0.38	43.7
Boll Weevil Sprays	546	0.18	0.03	0.00	4.00	10.6
Heliothine Sprays	546	0.59	0.03	0.00	5.00	43.9
Other Sprays	546	0.25	0.02	0.00	1.00	24.5
All Foliar Sprays	546	2.45	0.10	0.00	9.13	68.3
Total Treatments	546	3.15	0.11	0.00	11.13	68.5

Pinhead Square sprays were typically applied to the border of the fields to an area ~ 1/8 the total area of each field.

Total Treatments include all foliar sprays and Temik applications.

Other sprays were insecticide treatments directed at any pest not included in the list. Cutworm sprays were common in this category.

Table 3. Descriptive statistics associated with COTMAN data (average of multiple samples per field or field and month) in subset of Wild Farms production records, 1997-2002.

COTMAN Data	n	Mean	Standard Error	Minimum	Maximum
Julian Date of Cutout (NAWF = 5)	544	215.94	0.35	192.00	233.00
NAWF at Cutout	546	4.41	0.03	1.93	8.28
Days from Planting to Cutout	546	92.65	0.48	58.00	180.00
Julian Date of Planting	544	123.57	0.30	109.00	138.00
No. Sympodia in June	541	4.19	0.05	1.58	7.90
Days from Planting to Average Sample Date in June	541	47.62	0.25	33.50	62.50
Plant Height in June (inches)	541	12.75	0.10	6.63	22.38
Height to Node Ratio in June	541	1.37	0.01	0.78	2.03
Total Plant Nodes in June	541	9.15	0.04	6.06	12.44
% Retention of 1st Position Fruit on Third Sympodia From Top in June	541	94.30	0.27	57.14	100.00
% Retention of Top 3 Fruiting Positions in June	541	97.44	0.13	75.81	100.00
% Retention of Squares in June	541	94.39	0.22	69.42	100.00
% Retention of All 1st Position Fruit in June (same as squares in June)	541	94.39	0.22	69.42	100.00
No. Sympodia in July	540	9.36	0.05	5.40	13.21
Days from Planting to Avg. Sample Date in July	540	70.62	0.30	54.89	86.00
Plant Height in July (inches)	540	27.93	0.20	15.33	40.19
Height to Node Ratio in July	540	1.92	0.01	1.17	2.70
Total. Plant Nodes in July	540	14.33	0.05	10.56	17.75
% Retention of 1st Position Fruit on Third Sympodia from Top in July	540	96.62	0.13	80.83	100.00
% Retention of Top 3 Fruiting Positions in July	540	98.42	0.08	82.91	100.00
% Retention of Squares in July	540	92.90	0.16	73.38	99.61
% Retention of All 1st Position Fruit in July	540	90.25	0.19	73.30	99.11
No. Sympodia Nodes in August	545	13.53	0.07	7.29	17.88
Days from Planting to Avg. Sample Date in August	545	96.82	0.31	79.50	112.00
Plant Height in August (inches)	545	39.72	0.26	20.44	58.25
Height to Node Ratio in August	545	2.15	0.01	1.48	3.02
Total Plant Nodes in August	545	18.50	0.07	13.77	24.15
% Retention of 1st Position Fruit on Third Sympodia From Top in August	545	89.15	0.57	10.00	100.00
% Retention of Top 3 Fruiting Positions in August	544	91.27	0.59	6.61	100.00
% Retention of Squares in August	544	86.02	0.63	5.45	100.00
% Retention of All 1st Position Fruit in August	545	75.75	0.40	34.72	93.45

NAWF refers to nodes above white flower.

Average sample data is a relative time typically based on dates of four weekly samples during each month.

Height to node ratio is expressed as average internode length in inches.

Table 4. Correlation coefficients (r) observed in linear comparisons of Insecticide use patterns with yield, total insecticide use, and date of crop cutout (NAWF=5) in subset of Wildy Farms production records, 1997-2002.

Variable	1st Pick Yield	Total Yield	Number of Insecticide Treatments	Date of Cutout (NAWF 5)
No. Aldicarb Applications	-0.048	-0.047	0.801***	-0.001
No. Aphid Sprays	-0.111	-0.114	0.255**	-0.245**
No. Armyworm Sprays	-0.153*	-0.162*	0.165*	-0.031
No. Plant Bug Sprays	0.230**	0.230**	0.519***	-0.024
No. Spider Mite Sprays	0.096	0.075	0.293**	-0.027
No. Thrips Sprays	0.132	0.135*	0.711***	0.145*
No. Pinhead Sq. Sprays	-0.357***	-0.349***	0.463***	-0.101
No. Boll Weevil Sprays	0.063	0.071	0.484***	0.168*
No. Heliothine Sprays	-0.060	-0.058	0.558***	-0.003
No. Other Sprays	0.252**	0.256**	0.498***	0.057
Total No. Foliar Sprays	0.134*	0.134*	0.991***	0.046
Total No. Insecticide Treatments	0.106	0.107	----	0.039

*, **, *** indicate significant correlation coefficients at P<0.05, P<0.01, and P<0.001, respectively.

Table 5. Correlation coefficients resulting from linear comparisons of COTMAN crop growth indices with yield, insecticide use, and cutout (NAWF=5) in subset of Wildy Farms production records, 1997-2002.

Variable	1st Pick Yield	Total Yield	Number of Insecticide Treatments	Date of Cutout (NAWF 5)
Date of NAWF=5	0.316***	0.319***	0.039	1.000***
NAWF at Detection of NAWF=5	-0.029	-0.033	-0.097	-0.007
Days from Planting to NAWF=5	0.469***	0.483***	0.138*	0.738***
Date of Planting	-0.461***	-0.478***	-0.164*	0.083
No. Squaring Nodes in June	0.125	0.123	0.212**	-0.370***
Days from Planting to June Sample	0.353***	0.372***	0.182*	0.044
Average Plant Height in June	0.081	0.078	0.134*	-0.425***
Height to Node Ratio in June	0.183*	0.183*	0.042	-0.352***
No. Plant Nodes in June	-0.090	0.096	0.193*	-0.286**
No. Squaring Nodes in July	0.366***	0.365***	0.135*	-0.254**
Days from Planting to July Sample	0.416***	0.429***	0.146*	-0.159*
Average Plant Height in July	0.393***	0.384***	0.093	-0.177*
Height to Node Ratio in July	0.362***	0.352***	0.071	-0.160*
No. Plant Nodes in July	0.199*	0.196*	0.101	-0.183*
No. Squaring Nodes in August	0.440***	0.444***	-0.060	0.166*
Days from Planting to August Sample	0.446***	0.460***	0.138*	-0.002
Average Plant Height in August	0.640***	0.643***	0.059	0.216**
Height to Node Ratio in August	0.536***	0.550***	0.122	0.100
No. Plant Nodes in August	0.269**	0.274**	-0.083	0.230**

*, **, *** indicate significant correlation coefficients at P<0.05, P<0.01, and P<0.001, respectively.

Table 6. Correlation coefficients r observed in linear comparisons of different measurements of % fruit retention, yield, total insecticide use, and date of cutout (NAWF=5) in subset of Wildy Farms production records, 1997-2002.

Variable	1st Pick Yield	Total Yield	Number of Insecticide Treatments	Date of Cutout (NAWF)
% Retention of 3rd Position in June	-0.090	-0.110	-0.086	0.089
% Retention of Top 3 Positions in June	-0.085	-0.104	-0.082	0.094
% Retention of Squares in June	-0.143*	-0.161*	-0.151*	0.120
% Retention of All 1st Positions in June	-0.143*	-0.161*	-0.151*	0.121
% Retention of 3rd Position in July	0.283**	0.285**	0.051	0.275**
% Retention of Top 3 Positions in July	0.239**	0.239**	0.027	0.324***
% Retention of Squares in July	0.242**	0.230**	-0.094	0.251**
% Retention of All 1st Positions in July	0.035	0.025	-0.116	0.321***
% Retention of 3rd Position in August	0.382***	0.398***	0.068	0.398***
% Retention of Top 3 Positions in August	0.354***	0.366***	0.027	0.343***
% Retention of Squares in August	0.441***	0.454***	0.045	0.413***
% Retention of All 1st Positions in August	0.106	0.115	-0.009	0.371***

*, **, *** indicate significant correlation coefficients at P<0.05, P<0.01, and P<0.001, respectively.

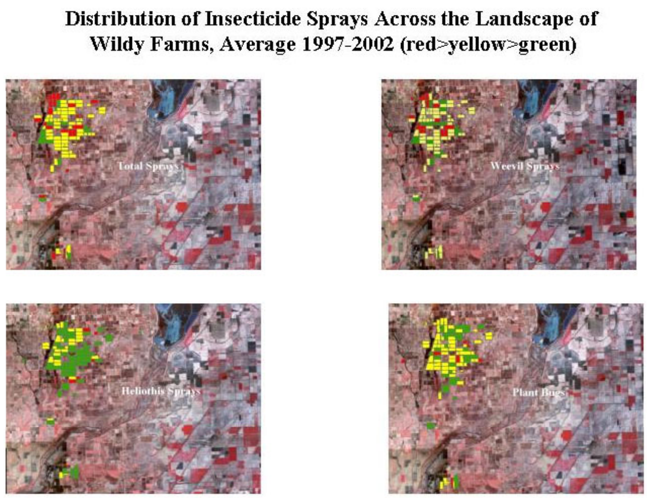

Figure 1. Spatial distribution of total insecticide sprays and sprays for boll weevil, bollworm and tobacco budworm, and plant bugs across Wildy Farms, 1997-2002.

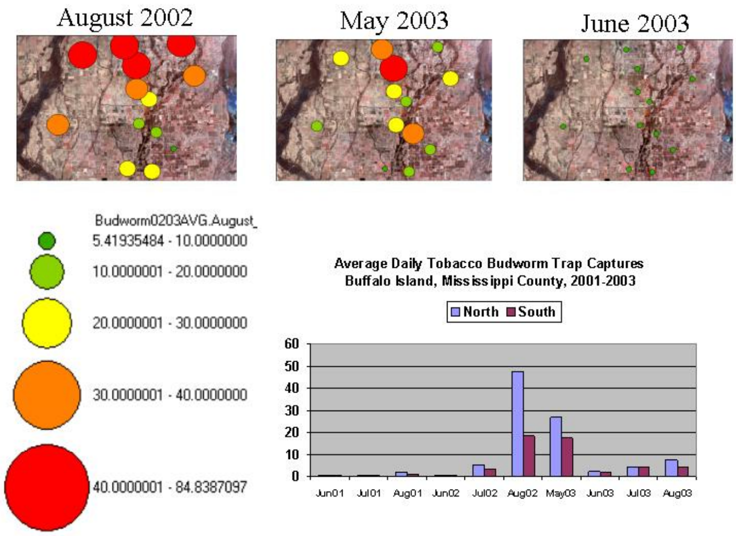

Figure 2. Spatial distribution of tobacco budworm trap captures across the Buffalo Island area during August 2002, May 2003, and June 2003.