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Observations of First Occurrence and Severity of Potato Leafhopper, *Empoasca Fabae* (Harris), (Homoptera: Cicadellidae) in the North Central and Eastern United States.

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OBSERVATIONS OF FIRST OCCURRENCE AND SEVERITY OF POTATO LEAFHOPPER, *EMPOASCA FABAE* (HARRIS), (HOMOPTERA: CICADELLIDAE) IN THE NORTH CENTRAL AND EASTERN UNITED STATES.

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ABSTRACT

This paper presents available data on the first occurrence dates and the damage severity of the potato leafhopper in the north central and north eastern United States collected during the past 47 years (1951–1997). The data were collected from a variety of sources including: potato leafhopper literature review; published reports; pest alerts; pest surveys; and delphi surveys. First occurrence and severity data show that the arrival time of potato leafhopper and subsequent damage severity varies substantially from year to year. A correlation analysis between date of first occurrence and severity of damage for Michigan, Minnesota, Wisconsin, the north central region and the northeastern region indicated no significant relationship between first arrival dates and damage severity. The lack of a relationship between the time of arrival of the migrant leafhopper and severity indicate that other factors, including frequency and magnitude of arrivals, weather conditions during the growing season and crop management contribute to the eventual severity of damage caused to crops by this migratory pest. The analysis of potato leafhopper severity data showed significant differences between years. There were no significant differences in severity among states within the north central region, indicating that potato leafhopper severity is a regional phenomenon.

The potato leafhopper, *Empoasca fabae* (Harris), is a serious pest on a wide variety of agricultural crops including alfalfa, potato and soybean. Potato leafhopper have the potential to cause severe economic loss to crops in most mid-western and eastern states of the United States. Poos and Johnson (1936) reported yield reduction in alfalfa of 13 to 27% due to potato leafhopper damage. In Maryland and Minnesota, annual losses from potato leafhopper damage to alfalfa and potatoes have been estimated at $66/ha and $290/ha, respectively (Lamp et al. 1991; Noetzel et al. 1985). In addition to agricultural crops, potato leafhopper is also known to utilize over 100 species of host plants including clovers, broadleaf weeds, grasses, ornamental plants

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and trees (Poos and Wheeler 1943, Medler 1957, Hogg 1985, Lamp et. al. 1994).

The potato leafhopper is a multivoltine sucking insect. Using a combination of probing and sucking behaviors, adults and nymphs remove plant sap directly from the vascular (water and food transport) system in the leaflet, petioles and stem of the plant. The mechanical damage and the proteins present in the saliva result in disruption of phloem tissue structure and translocation processes (Kabrick and Backus 1990, Ecale and Backus 1994). Injured plants have reduced rates of photosynthesis and transpiration (Womack 1984, Flinn et al. 1990). Damage is expressed by reduced rates of maturation, growth and nutrient levels (Hutchins et al. 1990, Cuperus et al. 1983, Lamp et al. 1985)

The potato leafhopper does not overwinter in the north central and northeastern states. It is known to overwinter as an adult along the Gulf of Mexico and migrate northward each spring (Poos 1932, De Long and Caldwell 1935, De Long 1938, Medler 1941, Flanders and Radcliff 1989, Carlson et. al. 1992). Decker and Cunningham (1968) conclude that overwintering sites of potato leafhopper are limited to areas which have frost-free periods of at least 260–270 days. Potato leafhopper overwinters primarily in southern Louisiana and northern Florida (Decker and Cunningham 1968), but changes in the overwintering distribution have been observed (Taylor and Shields 1995a). An increase in population occurs in the overwintering area from February through April (Medler 1962, Taylor and Shields 1995b), potentially resulting in large numbers of potato leafhopper in the lower Mississippi River Valley area mid-April through early May (Decker 1959). These populations are believed to be the source of the potato leafhopper influxes in the northern United States during April, May and June (Pienkowski and Medler 1964). Populations of potato leafhopper can move over long distances on synoptic weather fronts over short periods of time (Pienkowski and Medler 1964, Carlson et al. 1992).

The potato leafhopper damage severity and economic loss in the north central and eastern United States during a given year depends on several factors including: time of arrival, frequency and magnitude of arrival, weather conditions at arrival time, crop and pest management practices and weather conditions during the growing season. Because potato leafhopper is a migratory insect, time of arrival can be very important in terms of number of generations produced and abundance during a given year. It is the generations resulting from this initial colonization which cause economic loss to commercial crops.

In the north central and eastern United States, potato leafhopper management strategies during years when there is an early and large influx of migrants can be critical to prevent potato leafhopper damage. However, the inability to accurately predict arrival and magnitude of the potato leafhopper migration from its overwintering sites in southern U.S.A. reduces management strategies to a reactive rather than proactive process. In some north central and eastern states, large influxes of adult leafhoppers may arrive aboard a single weather system with no current or prior warning and result in major economic loss to local crops before detection and management. The development of preventive pest management strategies for potato leafhopper requires knowledge and understanding of the relationship between weather (episodic meteorological events surrounding potato leafhopper arrival) and pest status and accurate prediction of their arrival. With the rapid advancement in computer tools and technologies and the availability of historical climate data sets, new predictive strategies can be developed for pests such as potato leafhopper.

To efficiently utilize the computer technology and climate databases to understand potato leafhopper migration and develop preventative approaches to damage reduction and risk prediction, it will require long-term data sets on potato leafhopper first occurrence and severity. The objective of this study was to compile all available information on potato leafhopper first occurrence and damage severity, and to examine the relationship between time of arrival and subsequent severity.

METHODS

A multi-state cooperative network composed of 16 states and 23 investigators (Table 1) was established to obtain and consolidate available dates of first occurrence and damage severity of potato leafhopper in north central and eastern United States since 1951. Severity was classed into five categories; 1 = Low (Less than 20% of crop acreage (alfalfa, other) exceeding economic threshold). 2 = Moderate (20–40% crop acreage exceeding economic threshold). 3 = Heavy (40–60% crop acreage exceeding economic threshold). 4 = Severe (60–80% crop acreage exceeding economic threshold). 5 = Very severe (80% or above of crop acreage exceeding economic threshold).

Information sources included: potato leafhopper literature review, Cooperative Agricultural Pests survey (CAPS) network database, annual reports

Table 1. Cooperators

State	Cooperators	Institutions
Illinois	S.J Roberts, E. J. Armbust	University of Illinois
Indiana	L.W. Bledsoe	Purdue University
Iowa	M. E. Rice	Iowa State University
Kentucky	B. C. Pass	University of Kentucky
Maryland	W. O. Lamp	University of Maryland
Michigan	M. E. Whalon, D. A. Landis, S. H. Gage, K. M. Maredia, J. Andresen, M. J. Kaeb	Michigan State University
Minnesota	K. Flanders, E. B. Radcliffe, W. D. Hutchison	University of Minnesota
Missouri	W. C. Bailey	University of Missouri
Nebraska	S. D. Danielson	University of North Dakota
New York	E. J. Shields	Cornell University
North Dakota	S. D. Danielson	University of North Dakota
Ohio	J. K. Flessel, R. B. Hammond	Ohio State University
Oklahoma	R. C. Berberet	Oklahoma State University
Pennsylvania	A. A. Hower	Pennsylvania State University
Virginia	R. L. Pienkowski	Virginia Polytechnic Institute
Wisconsin	D. B. Hogg	University of Wisconsin

Table 2. Sources used for gathering Potato Leafhopper first occurrence and severity data.

Data received from cooperators working on potato leafhopper through delphi survey (information mainly from NCR-193 group) (Table 6)
Potato leafhopper data from Cooperative Agricultural Pests Survey (CAPS) database (1988-91)
NC-193 annual reports (1990–91): Spatial dynamics of leafhopper pest and their management on alfalfa.
NCR-149 annual reports (1980–1980): Pest management strategies for leafhoppers, spittle bugs and aphids on alfalfa.
Pest Alerts published by Michigan State University Cooperative Extension Service (1971–86)
Potato leafhopper summaries compiled by Dr. George C. Decker, former Director of Center for Economic Entomology, University of Illinois (1951–68).
Peterson, A. G., J. D. Bates and Saini, R. S. 1969. Spring dispersal of some leafhoppers and aphids. Journal of Minnesota Academy of Sciences. 35 (2):98–102.
Medler, J. T. 1957. Migration of potato leafhopper—a report on a cooperative study. Journal of Economic Entomology. 50:492–497.
Pienkowski, R. L. and J. T. Medler. 1964. Synoptic weather conditions associated with the long-range movement of the potato leafhopper, *Empoasca fabae*, into Wisconsin. Annals of Entomological Society of America. 57:588–591.

of North Central Regional (NCR) research projects (NCR-149 and NCR-193), Pest Alerts published by Michigan State University Cooperative Extension Service and potato leafhopper summaries compiled by Dr. George C. Decker, University of Illinois. In addition a delphi survey was conducted to obtain information from cooperators working on potato leafhopper (Table 1). The details of the above sources are given in Table 2.

A correlation analysis between first occurrence dates and damage severity was conducted for three individual states and for the north central and north eastern regions to examine the relationship between the time of arrival and severity. The analysis was done for Michigan, Minnesota and Wisconsin, as these states had the largest number of observations available.

RESULTS

The data on the first occurrence of the potato leafhopper migrants in the north central (Table 3) and north eastern (Table 5) United States show that the arrival time of potato leafhopper varies substantially from year to year (mid-April to early June). Severity of potato leafhopper damage in the north central (Table 4) and northeastern (Table 6) United States also shows wide variability (1–5) from year to year (Smith and Medler 1959, Hutchins and Pedigo 1990). The earliest date of arrival in north central states is March 23, the latest date is June 13 with a mode of May 11 to May 20 (46 observations) (Table 3). In the northeastern states the earliest date of arrival is March 27, the latest date is June 21 with a mode of June 1 to June 10 (15 observations) (Table 5).

Table 3. Dates of first occurrence of Potato leafhopper in the North Central United States.

Year	MI	WI	IL	OH	IA	IN	KY	MN	NE	ND	SD	MO	KS	OK
1951	*	5/23	*	*	*	*	*	*	*	*	*	*	*	*
1952	*	5/15	5/13	5/16	5/23	4/8	*	6/2	6/15	*	6/3	5/8	6/3	6/1
1953	6/11	5/20	5/11	5/19	4/27	*	*	5/25	5/22	5/21	5/29	5/9	*	*
1954	5/26	5/26	4/26	4/21	5/23	*	*	5/25	5/27	5/17	*	E May	5/27	5/22
1955	4/16	5/26	5/11	5/30	6/3	6/3	*	5/21	5/18	6/13	*	4/20	5/17	5/3
1956	5/29	5/16	5/7	5/14	5/12	5/14	*	5/22	3/23	6/3	5/15	5/15	5/11	5/11
1957	*	5/15	*	*	*	5/7	*	5/23	5/15	7/19	6/10	4/30	*	*
1958	*	5/22	*	5/11	*	*	*	5/23	5/5	6/6	5/29	*	*	5/20
1959	*	4/26	5/5	5/19	*	*	*	5/12	4/28	6/12	6/12	*	*	*
1960	*	5/24	5/4	*	*	*	*	5/17	*	6/7	6/27	Md July	*	*
1961	*	5/13	5/11	*	*	*	*	5/22	*	6/16	3W June	*	*	*
1962	*	5/15	*	*	*	*	*	*	*	*	*	*	*	*
1963	*	*	4/21	*	*	*	*	*	*	*	*	*	*	*
1964	Lt May	5/8	3/27	6/5	*	*	*	*	*	*	*	*	*	*
1965	5/18	2W May	4/26	*	*	*	*	*	*	*	*	5/6	*	*
1966	5/20	*	E May	*	*	*	*	*	*	*	*	*	*	*
1967	6/12	Md June	5/1–12	*	*	5/1	*	*	*	*	*	*	*	*
1968	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1969	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1970	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1971	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1972	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1973	6/4	*	*	*	*	*	*	*	*	*	*	*	*	*
1974	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1975	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1976	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1977	Md May	*	*	*	*	*	*	*	*	*	*	*	*	*
1978	6/10–11	*	*	*	*	*	*	*	*	*	*	*	*	*
1979	5/16	*	*	*	*	*	*	*	*	*	*	*	*	*
1980	6/6–12	5/12	*	*	*	*	5/13	*	*	*	*	*	*	5/19
1981	*	4/15	4/26	5/18	*	*	5/4	*	*	*	*	*	*	5/14
1982	*	5/10	5/5	5/27	*	*	5/7	*	*	*	*	5/7	*	5/22

(*Continued*)

Table 3. (*Continued*).

Year	MI	WI	IL	OH	IA	IN	KY	MN	NE	ND	SD	MO	KS	OK
1983	5/30	5/26	5/1	6/1	*	*	5/9	*	*	*	*	5/9	*	5/22
1984	*	5/23	5/14	5/24	*	*	5/18	6/4	*	*	*	5/11	*	5/18
1985	5/17	5/6	4/25	5/7	*	*	5/10	5/9	5/7	*	*	5/10	*	5/30
1986	*	5/7	*	5/9	*	*	5/7	6/19	5/6	*	*	5/6	*	5/21
1987	5/29	5/11	*	5/21	*	*	5/8	5/13	*	*	*	5/8	*	5/8
1988	5/16	5/10	5/9	5/12	*	6/1	5/9	5/11	5/17	*	*	6/13	*	5/4
1989	5/21–27	5/10	5/23	5/22	*	5/22	5/17	5/22	6/6	*	*	5/24	*	5/28
1990	4/23	5/7	5/1	5/14	5/22	*	4/26	5/31	*	*	*	5/11	*	4/22
1991	5/29	5/8	5/6	5/9	*	4/26	4/29	5/22	*	*	*	4/25	*	4/25
1992	5/6	5/11	4/22	4/15–20	5/4	5/4	5/4	5/13	4/14–28	*	*	4/21	*	4/16
1993	5/11	*	*	*	*	*	*	*	*	*	*	*	*	4/30
1994	5/3	5/5	*	*	*	*	4/22	*	*	*	*	*	*	4/23
1995	5/15	5/22	4/13	5/11	*	*	4/25	5/25	*	*	*	5/5	*	4/29
1996	5/7	6/11	5/20	5/6	*	*	5/9	6/27	*	*	*	*	*	4/27
1997	5/6	6/9	4/16	5/5	*	*	5/5	6/16	*	*	*	*	*	4/22

* = Missing data; Lt = Late; Md = Mid; E=Early; W = Week; WE = week ending.

Table 4. Severity of potato leafhopper in north central United States.**

Year	MI	WI	IL	OH	IA	IN	KY	MN	NE	ND	SD	MO	KS	OK
1951	*	2	*	2	*	*	*	*	*	2	*	*	*	*
1952	*	4	4	4	*	5	*	4	2	*	3	*	*	*
1953	5	4	*	4	5	*	*	4	*	*	3	3	2	1
1954	3	3	3	3	3	3	*	2	3	*	*	1	*	1
1955	*	3	3	3	*	3	*	*	3	4	3	3	*	2
1956	*	4	3	2	*	*	*	2	3	3	3	3	*	2
1957	*	3	4	3	*	3	*	2	4	2	3	5	*	*
1958	*	2	1	1	*	*	*	1	1	1	1	1	*	*
1959	*	*	*	2	*	3	*	*	2	3	1	*	*	*
1960	*	1	1	*	2	*	*	*	*	3	2	2	2	*
1961	*	4	3	4	*	3	*	1	3	1	1	*	*	*
1962	1	3	2	4	*	3	*	*	1	1	*	2	*	*
1963	*	2	1	2	*	*	*	*	1	*	*	1	*	*
1964	3	3	3	4	*	3	*	*	2	*	*	3	*	*
1965	*	3	2	1	*	2	*	3	1	*	*	2	*	*
1966	2	3	3	1	*	2	*	3	3	1	*	*	1	*
1967	3	2	*	4	*	3	*	3	*	*	*	3	*	*
1968	*	*	*	*	*	*	*	3	*	*	*	*	*	*
1969	*	*	*	*	*	*	*	3	*	*	*	*	*	*
1970	*	*	*	*	*	*	*	2	*	*	*	*	*	*
1971	2	*	*	*	*	*	*	2	*	*	*	*	*	*
1972	*	*	*	*	*	*	*	2	*	*	*	*	*	*
1973	2	*	*	*	*	*	*	1	*	*	*	*	*	*
1974	*	*	*	*	*	*	*	2	*	*	*	*	*	*
1975	*	*	*	*	*	*	*	3	*	*	*	*	*	*
1976	2	*	*	*	*	*	*	2	*	*	*	*	*	*
1977	2	*	*	*	*	*	*	2	*	*	*	*	*	*
1978	3	*		*	*	*	*	2	*	*	*	*	*	*
1979	4	*	*	*	*	*	3	2	*	*	*	*	*	*
1980	1	*	*	*	*	1	*	1	*	*	*	*	*	1
1981	5	*	4	4	*	5	4	3	*	*	*	*	*	1
1982	3	*	*	2	*	*	2	3	*	*	*	*	*	1
1983	4	*	4	1	*	4	1	5	*	*	*	4	*	1
1984	2	*	1	1	*	*	1	1	*	*	*	*	*	1
1985	2	*	*	*	*	*	1	2	*	*	*	1	*	1
1986	*	*	*	*	*	4	4	2	5	*	*	2	*	1
1987	*	*	*	*	*	*	1	2	2	*	*	1	*	1
1988	1	*	*	1	*	*	1	2	2	*	*	1	*	1
1989	3	2	*	*	*	*	2	2	*	*	*	2	*	1
1990	3	*	3	*	*	*	2	3	*	*	*	2	*	1
1991	4	*	*	*	*	*	2	4	*	*	*	1	*	1
1992	1	3	3	4	3	2	1	4	4	*	*	2	*	2
1993	3	*	*	*	*	*	*	4	*	*	*	*	*	2
1994	2	*	*	*	*	*	*	4	*	*	*	*	*	1
1995	4	*	*	*	*	*	*	4	*	*	*	*	*	2
1996	3	*	*	*	*	*	*	2	*	*	*	*	*	1
1997	2	*	*	*	*	*	*	5	*	*	*	*	*	2

* Missing Data.

** Severity on a 1 to 5 scale, where 1 = low, 2 = moderate, 3 = heavy, 4 = severe, 5 = very severe.

Table 5. Dates of the first occurrence of potato leafhopper in the north eastern United States.

Year	NY	NJ	DL	MD	MA	NH	PA	VT	RI	VI
1951	*	*	*	*	*	*	*	*	*	*
1952	*	*	*	*	*	*	*	*	*	*
1953	6/2	*	5/29	6/15–20	*	*	*	*	*	5/29
1954	6/8	*	*	*	*	*	*	*	*	5/1
1955	*	*	6/10	6/10	*	*	6/3	*	*	*
1956	6/5	*	*	*	*	*	*	*	*	*
1957	3/27	*	*	5/22	*	*	Lt May	*	*	*
1958	6/19	*	*	*	*	*	*	*	*	*
1959	*	*	5/22	6/5	*	*	*	*	*	*
1960	6/6	*	Lt May	*	5/28	*	*	*	*	*
1961	6/21	*	*	6/6	5/23	*	*	*	*	*
1962	*	*	*	*	*	*	*	*	*	*
1963	*	*	5/31	6/4	*	*	*	*	*	*
1964	*	*	*	*	*	*	*	*	*	*
1965	*	*	*	5/19	*	*	*	*	*	*
1966	*	*	*	6/7	*	*	*	*	*	*
1967	*	*	*	6/5	*	*	*	*	*	*
1968	*	*	*	*	*	*	*	*	*	*
1969	*	*	*	*	*	*	*	*	*	*
1970	*	*	*	*	*	*	*	*	*	*
1971	*	*	*	*	*	*	*	*	*	*
1972	*	*	*	*	*	*	*	*	*	*
1973	*	*	*	*	*	*	*	*	*	*
1974	*	*	*	*	*	*	*	*	*	*
1975	*	*	*	*	*	*	*	*	*	*
1976	*	*	*	*	*	*	*	*	*	*
1977	*	*	*	*	*	*	*	*	*	*
1978	*	*	*	*	*	*	*	*	*	*
1979	*	*	*	*	*	*	*	*	*	*
1980	*	*	*	*	*	*	*	*	*	*
1981	*	*	*	*	*	*	*	*	*	*
1982	*	*	*	*	*	*	*	*	*	*
1983	*	*	*	*	*	*	*	*	*	5/24–27
1984	*	*	*	*	*	*	*	*	*	*
1985	*	*	*	*	*	*	*	*	*	*
1986	*	*	*	5/16	*	*	*	*	*	*
1987	*	*	*	5/14	*	*	*	*	*	*
1988	6/4	*	*	5/11	5/16	6/13	5/24	*	*	5/17
1989	5/28	*	*	5/21–25	*	*	5/25	*	*	5/12–16
1990	5/7	5/23	*	4/23	6/8	6/4	5/9	*	*	4/25
1991	5/16	5/13	*	5/10	5/20	5/22	5/14	*	*	4/25
1992	6/9	*	*	4/29	*	*	5/24	*	*	4/29
1993	*	*	*	5/7	*	*	*	*	*	*
1994	*	*	*	4/26	*	*	*	*	*	*
1995	*	*	*	5/8	*	*	*	*	*	*
1996	*	*	*	4/19	*	*	*	*	*	*
1997	Lt. May	*	*	5/12	*	*	*	*	*	*

* Missing Data; Lt = Late

Table 6. Severity of potato leafhopper in the north eastern United States. **

Year	NY	NJ	DL	MD	MA	NH	PA	VT	RI	VI
1951	1	1	3	3	*	*	3	*	*	*
1952	4	3	4	4	3	2	*	3	*	2
1953	5	*	5	3	*	*	4	*	*	4
1954	*	3	1	2	*	*	3	*	*	3
1955	2	*	1	1	*	*	2	*	*	3
1956	*	2	4	2	*	*	4	*	*	*
1957	3	1	2	3	*	*	4	*	*	3
1958	*	1	1	1	1	*	1	*	*	1
1959	*	*	2	*	*	*	*	*	*	2
1960	*	*	2	3	*	*	*	*	*	3
1961	1	2	2	4	3	*	2	*	2	*
1962	2	2	*	3	3	*	2	4	2	2
1963	3	3	*	3	*	*	*	3	*	*
1964	*	3	3	4	2	*	2	3	*	*
1965	3	2	3	4	*	*	2	4	*	*
1966	*	1	3	3	*	*	1	3	*	*
1967	4	2	3	2	*	*	4	*	*	3
1968	*	*	*	2	*	*	*	*	*	*
1969	*	*	*	*	*	*	*	*	*	*
1970	*	*	*	*	*	*	*	*	*	*
1971	*	*	*	*	*	*	*	*	*	*
1972	*	*	*	*	*	*	*	*	*	*
1973	*	*	*	*	*	*	*	*	*	*
1974	*	*	*	*	*	*	*	*	*	*
1975	*	*	*	*	*	*	*	*	*	*
1976	*	*	*	3	*	*	*	*	*	*
1977	*	*	*	2	*	*	*	*	*	*
1978	*	*	*	3	*	*	*	*	*	*
1979	*	*	*	3	*	*	*	*	*	*
1980	*	*	*	3	*	*	*	*	*	*
1981	*	*	*	3	*	*	*	*	*	*
1982	*	*	*	3	*	*	*	*	*	*
1983	*	*	*	3	*	*	1	*	*	*
1984	*	*	*	4	*	*	*	*	*	*
1985	*	*	*	3	*	*	*	*	*	*
1986	*	*	*	3	*	*	*	*	*	*
1987	3	*	*	4	*	*	4	*	*	*
1988	1	*	*	3	*	*	*	*	*	*
1989	3	*	*	3	*	*	2	*	*	2
1990	4	*	*	4	*	*	1	*	*	4
1991	4	*	*	4	*	*	1	*	*	4
1992	1	*	*	3	*	*	1	*	*	2
1993	*	*	*	4	*	*	*	*	*	*
1994	*	*	*	3	*	*	*	*	*	*
1995	*	*	*	4	*	*	*	*	*	*
1996	*	*	*	3	*	*	*	*	*	*
1997	*	*	*	5	*	*	*	*	*	*

* Missing Data.

** Severity on a 1 to 5 scale, where 1 = low, 2 = moderate, 3 = heavy, 4 = severe, 5 = very severe.

Table 7. Correlation coefficient of potato leafhopper first occurrence dates and severity for selected states, North Central and North Eastern regions.

State or Region	R square value
Michigan	0.47
Minnesota	–0.06
Wisconsin	–0.03
North Central Region	–0.08
North Eastern Region	–0.29

Note: R square values calculated using Spearman's correlation method.
NS = Non significant at P= 0.05

The analysis of variance of potato leafhopper severity data for the north central and north eastern regions showed significant differences between years ($P > 0.05$). However, there were no significant differences in severity among states within the north central region. This indicates that potato leafhopper severity is a regional phenomenon (see Table 4, years 1958 and 1981). A correlation analysis conducted between first occurrence dates and severity for Michigan, Minnesota, Wisconsin, the north central region and the north eastern region showed that no significant relationship was observed between time of arrival and subsequent damage severity ($P > 0.05$) (Table 7). The lack of a significant relationship between the time of arrival of the migrant leafhoppers and damage severity indicates that other factors, including frequency and magnitude of arrivals, weather conditions during the growing season and crop management practices contribute to the eventual damage severity caused to crops by the potato leafhopper.

DISCUSSION

It is generally assumed that the earlier a migrant arrives in an area the more severe the damage to the crops. The data analysis from this study shows a poor association between time of arrival and severity of damage. Severity is a complex phenomenon governed by several interacting components of which time of arrival is a contributing factor.

The data set presented here on the first occurrence and severity of potato leafhopper in north central and eastern United States is not comprehensive. There are many missing data points as the information is not available or no monitoring was done. This data set should be periodically updated with new information as it becomes available. Missing data emphasizes the need for regional scale, standardized, regular and long term biological monitoring.

Since the potato leafhopper is a migratory pest, first arrival data can be combined with a meteorological database to determine the historical migration conditions (Huff 1963, Pienowski and Medler 1964). Together with known or inferred biological factors, this information can be useful to construct climatologies for first arrival of the potato leafhopper. These historical models could provide a risk assessment, enhance allocation of integrated pest management monitoring resources, and thus, enhance current management strategies for this pest on several important agricultural crops.

Historical pest information, such as the potato leafhopper database developed during this study, can have many other applications besides input to

preventive management models. The spatial dynamics of first occurrence and severity could be useful to researchers conducting long term ecological and economic studies on migratory insects. The data also could be useful to researchers studying trends in climate change using the potato leafhopper as an indicator species.

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