

Enumerating lepidopteran species associated with maize as a first step in risk assessment in the USA

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Pest management can have substantial impacts on non-target species both within and outside the units being managed. Assessment of these impacts is hampered by the lack of even the most basic checklist of the species present in most systems. The maize agroecosystem is of particular interest because of the large area covered and the intensity of widely varying forms of pest management. In this study a database of lepidopteran species that occur within the maize agroecosystem in the United States was compiled. The process was initiated by developing a list of plants present in maize using published sources and the first-hand knowledge of “weed” experts. This list of plant species associated with maize was then cross-listed with lepidopteran host feeding records using published sources. Finally, phenological profiles and conservation rankings were added. Although our list is not exhaustive, we found 132 plant species in 33 families associated with maize, and 229 lepidopteran species in 21 families that feed on these plants. The database of plants and lepidopteran species can be a starting point for assessment of risk to non-target Lepidoptera in maize from chemical control, biological control, and the use of transgenic *Bt* maize. The lepidopteran species associated with maize were found to be significantly less imperiled, as measured by their conservation rankings, than lepidopteran species as a whole in all habitats. This finding suggests that rare or endangered lepidopteran species are unlikely to be impacted by pest management in maize. Based on the likely lack of impact of pest management in maize on individual species, future studies should focus on potential impacts on the ecological services that lepidopteran species provide.

Keywords: *Bt* maize / transgenic / GMO / non-target species / risk assessment

INTRODUCTION

Pest management and conservation are the two major endeavors involved with the management of insect populations. Although they are often considered separate or even in conflict with each other, these two disciplines are inextricably linked and interdependent. The goal of insect pest management is to maintain insect pest species below threshold densities. Pest management tactics interfere with the ability of insects to survive, reproduce or exploit resources, and the impacts of these tactics are very rarely confined to the target pest species. These relatively broad effects clearly impinge on a substantial

proportion of insect habitats since, 70% of the land on earth is utilized for agriculture and forestry and presumably receives some level of pest management (Western, 1989). Two main goals of insect conservation are the preservation of rare insect species and of the ecological services that insect populations provide. Clearly, pest management practices can have important impacts on the conservation of insects and conversely, most managed systems could not function without the ecological services such as pollination, the biological control of pests, and decomposition of plant and animal tissue that

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insects provide. The first step towards a comprehensive insect management program that would provide adequate pest suppression, maintenance of ecological services, and minimal impact on rare species is a detailed assessment of which insect species are likely to exist in the managed system. Unfortunately, this baseline accounting of insect species is lacking for almost every managed system.

Here we describe a portion of the insect community associated with maize in the United States. The maize system is of particular interest because it outranks all other cultivated crops in the USA in terms of overall value, land area covered, and total pesticides used (U.S. Grains Council, 2002). Over 240 million metric tons of maize were produced in the USA in 2001, which was just over 41% of worldwide maize production (FAS-USDA, 2002). In the USA, maize is valued at \$ 19 billion/year, it is grown on 32 million hectares, and over 100 million kilograms of pesticides are used annually (Economic Research Service-USDA, 2002; Padgitt et al., 2001). Pesticide usage consists primarily of insecticides that can directly impact non-target insects and herbicides that can impact insects indirectly by removing host plants. Considering the size of the maize system and the intensity of pest management applied to it, the potential for substantial impacts on nontarget insect species and services would appear to be high. Insects provide important ecological services in the maize system including contribution to the biological control of key pest insects and weeds.

The large area covered by maize production and the broad range of ecoregions encompassed would make an accounting of all insect species impractical for the scope of a single study. In this study we focus on species in the order Lepidoptera. The Lepidoptera were chosen because they include some of the major maize pests (e.g., *Ostrinia nubilalis*, and *Helioverpa zea*) and this taxon also contains a substantial number of rare or endangered species. In addition, one of the few pest management tactics that is specific to an insect order, the use of transgenic maize expressing a gene encoding a *Bacillus thuringiensis* endotoxin (hereafter referred to as *Bt* maize), is specific to Lepidoptera. Since Lepidoptera are generally not predaceous or parasitic, they do not contribute to the suppression of pest insects. Although there are few data on the ecological roles of most Lepidoptera in maize, it has been documented across several systems that many lepidopteran species contribute to the biological control of important weed species (Julien and Griffiths, 1998), and they provide alternate prey for the natural enemies of important pests (Biddinger et al., 1994; Pavuk and Stinner, 1991). An accounting of Lepidoptera in maize will greatly facilitate the design of management plans

that provide adequate pest suppression while maintaining ecological services and minimizing effects on rare species. The objective of this study is to provide a baseline list of the lepidopteran species that are likely to occur in and around maize in the continental USA.

RESULTS

The survey of plants associated with maize identified 132 species in 33 families. The plant families accounting for the most species were Poaceae with 28 and Asteraceae with 20 (Appendix 1). Several plant families were represented by a single species. More than half the species (51.5%) were ranked as rare in maize, while 35.6% were ranked as common and 12.9% were ranked as abundant.

The survey of lepidopteran species that feed on plants associated with maize identified 229 species in 21 families (Appendix 2). The lepidopteran families accounting for the most species were Noctuidae with 84 and Hesperidae with 31. Several lepidopteran families were represented by a single species. Approximately one quarter of the lepidopteran species was identified as feeding on more than one plant species.

The distributions of global and national conservation status ranks for lepidopteran species identified as associated with maize were significantly different than the distributions of ranks for all lepidopteran species ranked in the NatureServe database ($P < 0.0001$; Figs. 1 and 2). Higher proportions of lepidopteran species associated with maize were assigned higher ranks (denoting a more secure status) compared to the proportions of all ranked lepidopteran species. Specifically, 87.4% of maize species were assigned a rank of G5 (globally secure) and 83.7% were assigned a rank of N5 (nationally secure), compared with 55.4% and 27.9%, respectively, for all the lepidopteran species ranked in the NatureServe database.

Only one maize-associated species, the mottled duskywing, *Erynnis martialis* (Lepidoptera: Hesperidae), was assigned a rank below G4, denoting the species is at risk globally. It is important to note that although the kerner blue butterfly, *Lycaeides melissa samuelis* (Lepidoptera: Lycaenidae), is ranked at G5, it is arguably more endangered than the mottled duskywing. Both species occur on host plants that are associated with maize but the largest stands of kerner blue's primary host, wild lupine, grow in pine/oak savannahs that are rapidly disappearing due to fire suppression and development. Based on the rapid decline in its habitat the kerner blue has been placed on the United States endangered species list. Both the kerner blue and the monarch butterfly,

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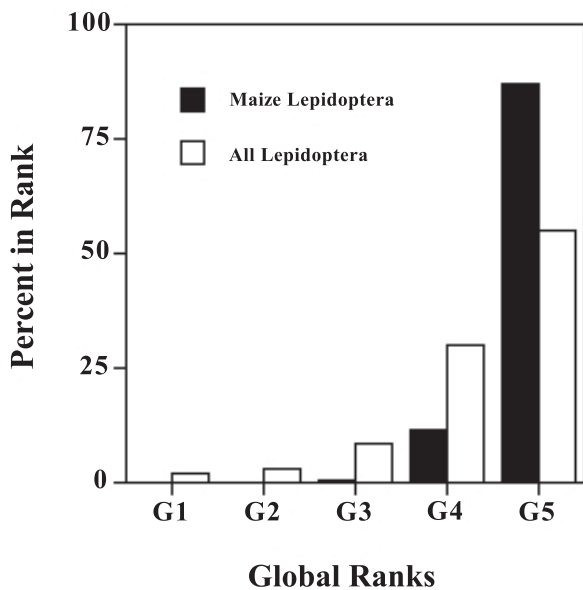


Figure 1. Frequency distribution for global conservation ranks of lepidopteran species. Black bars represent ranks of species associated with maize, and white bars represent species from all habitats combined.

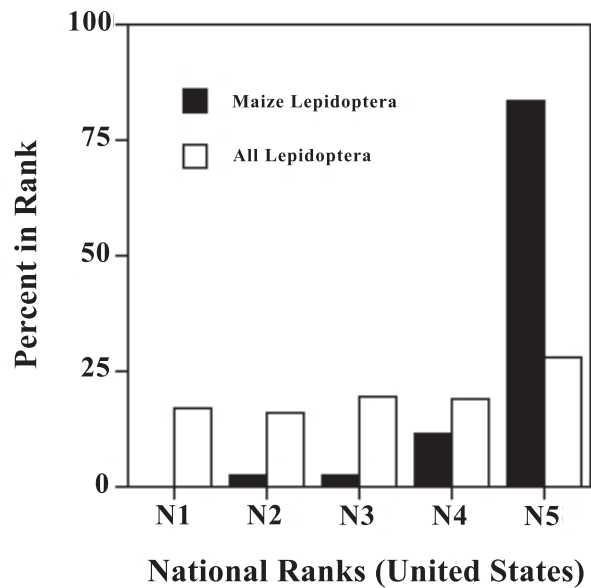


Figure 2. Frequency distribution for United States national conservation ranks of lepidopteran species. Black bars represent ranks of species associated with maize, and white bars represent species from all habitats combined.

Danaus plexippus (Lepidoptera: Nymphalidae), were assigned national ranks of N2 (nationally imperiled). The mottled duskywing and the southern scalloped sooty wing, *Staphylus mazans* (Lepidoptera: Hesperidae), were assigned ranks of N3 (nationally vulnerable). As illustrated by these examples, national ranks are often lower than global ranks because they represent a subset of all the populations of a species. Thus a species could be imperiled in several individual countries yet globally secure. All other ranked species associated with maize were assigned ranks of N4 or N5 that denote apparent or demonstrable security nationally.

DISCUSSION

The results of this survey show the unexpected complexity and diversity associated with the maize agroecosystem. Specifically they indicate clearly that there is a substantial number of lepidopteran species that feed on plants in and around fields of maize. This list of species can provide the basis for assessment of risk from a pest management tactic. Using this data set, species can be selected for more in-depth risk assessment based on their phenology and their security status. For example, univoltine species that go through their development in June could be given low priority for tactics applied in July and imperiled species

with low security ranks could be given higher priority than those with higher security status ranks.

When considering either the list of species or their relative security potential, sources of bias should be considered. Lepidopteran checklists are probably likely to have a bias towards more common species, while the data on species security is more complete for less secure species that are usually rare. Groups such as the microlepidoptera that have not been well studied are almost certainly underrepresented in most sources. While each individual source may miss several rare species, by consulting a large number of sources we are confident that we have assembled sufficient data to firmly ground our conclusions.

Once a group of species is selected, risk assessment could proceed by gathering data on: (1) the relative importance of maize as a habitat for the host plant; (2) the relative importance of that plant for the herbivore species; and (3) the susceptibility of the species to impact from the management tactic being assessed. Further information may be available on the relative importance of maize as a habitat for the host plant. Because most non-crop plants in and around maize fields are considered weeds, the make-up of these plant communities is fairly well known. Unfortunately, what is not known for most of the plants associated with maize is the proportion of their total

distribution that falls within a distance that is likely to be affected by a given pest management tactic. An additional complicating factor is that the adoption of reduced tillage systems has increased the diversity of plants occurring in agricultural fields (Cardina et al., 1991).

It is possible to gauge the relative importance of a given set of host plants for a lepidopteran species by more in-depth scrutiny of the species life history. Specialist herbivores feeding on plants that grow exclusively near maize fields are much more likely to be affected by pest management in maize than herbivores that feed on plants growing in several habitats, in addition to maize. This type of niche analysis for a large number of species would not be trivial, so it is probably best reserved for those species that are identified as high priority in the initial screen.

By combining the relative importance of maize as a habitat for the host plant and the relative utilization of that host plant by the herbivore species, it is possible to estimate the importance of maize fields as a habitat for the lepidopteran species being examined. The data gathered will be equally applicable to any pest management tactic. Conversely, data on susceptibility will be almost completely specific to the tactic being assessed. There is a large amount of published data available on the susceptibility of many lepidopteran species to chemical applications and smaller amounts of data available on the *Bt* toxin that is incorporated into transgenic maize (Johnson et al., 1995; Peacock et al., 1998), and the egg parasitoid *Trichogramma* that is used as an augmentative biological control agent (Hoffmann et al., 1995; Orr et al., 2000). Unfortunately, an assessment of the susceptibility of all the lepidopteran species associated with maize is not available for any of the tactics. In general, most lepidopteran species are physiologically susceptible to the insecticides used to control lepidopteran pests in maize. However, susceptibility to chemical insecticides is dependent on relative size and feeding niche. Small larvae feeding on exposed leaves will be more susceptible than large larvae feeding in a protected area like the roots or stalk of a plant.

In contrast to insecticides, physiological susceptibility to the *Bt* toxin varies widely within lepidopteran families and even within genera (Johnson et al., 1995; Peacock et al., 1998). This extreme variability essentially makes it impossible to establish a phylogenetic pattern that could guide the risk assessment process. Thus, a full assessment of any lepidopteran species for which no data on susceptibility to *Bt* exists may require standardized toxicity testing.

Among the three main tactics the fewest data exist for susceptibility to *Trichogramma* wasps. The challenge in

assessing risk for *Trichogramma* is that laboratory measures of physiological susceptibility (e.g. tests of oviposition in the eggs of a particular lepidopteran species) do not necessarily lead to accurate predictions of the level of non-target risk in the field. A current study, utilizing the database presented here, is assessing both the physiological and ecological susceptibility of a large group of lepidopteran species associated with maize to *Trichogramma ostrinia* (Wright et al., unpublished).

In addition to providing a list and biological information for more in-depth risk assessment, our review also uncovered an emergent property which applies generally to the complex of lepidopteran species that are associated with maize: only a very small proportion of the complex of lepidopteran species associated with maize are rare or endangered. In fact, this complex of species appears to have a lower proportion of rare or endangered species than the Lepidoptera as a whole. This is probably due to the large area covered by maize in a wide range of ecoregions and the fact that most of the plants associated with maize (e.g. weeds) are also adapted to thrive in other disturbed areas including other crops. In general, based on the prevalence of the maize habitat, any Lepidopteran that feeds on a plant associated with maize is probably not in immediate peril. The implication of this emergent property is that pest management tactics applied to maize are unlikely to affect an endangered or threatened lepidopteran species associated with non-maize plants that grow in and around maize fields.

The predicted lack of effects on endangered lepidopteran species does not mean that pest management tactics will not have negative impacts on the lepidopteran complex in maize as a whole. Many common lepidopteran species provide invaluable services such as the biological control of weeds (Julien and Griffiths, 1998), pollination (Buchmann and Nabhan, 1996), and alternate hosts for parasitoids of insect pests (Biddinger et al., 1994; Pavuk and Stinner, 1991). If pest management tactics depress lepidopteran densities, they may interfere with the provision of these services. If maize fields are serving as sources of the species providing these services in other systems, then even local depression of lepidopteran densities may cause disruption of the services on a regional basis. Thus, further assessment of the risk to the lepidopteran species associated with maize should focus on functional guilds as well as individual species.

MATERIALS AND METHODS

The first step in any risk assessment is developing a list of species that might be affected by the pest management

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tactics employed. Once a complete list is generated the relative level of risk can be estimated for each individual species. Our list is restricted to the top 17 maize producing states in the United States which are (in order of hectares planted to maize) IA, IL, NE, MN, IN, SD, WI, OH, KS, MO, MI, TX, PA, KY, CO, and NY. These 17 states account for over 90% of the maize planted in the United States (National Agricultural Statistics Service – USDA, 2000).

Since Lepidoptera are almost universally herbivorous, our first step in generating a list of lepidopteran species associated with maize was to determine which plant species were likely to be associated with this crop. The list of plant species in maize was generated through a combination of published data and personal knowledge (RGH) of plants in the maize system. The list is not intended to be exhaustive, but it does include most of the common and abundant plants, and illustrates the wide variety of plants associated with maize production. Each plant species was ranked as abundant, common, or rare by RGH.

The next step in our sequential approach was to determine which lepidopteran species feed on plants within the maize system. By cross-listing the plant species with the lepidopteran species that feed on these plants, an initial list of non-target herbivores was generated. All records of lepidopteran feeding on individual host plant species are based on published sources.

Once it had been determined which lepidopteran species feed on plant species in the maize system, the next step was to determine which of those herbivore species are feeding in the larval stage during the period when pest management tactics are likely to affect them. Since most pest management that would affect lepidopteran species in USA maize fields is undertaken in the summer months, we restricted our phenological profile to larval presence/absence in June, July and August. This phenological overlap with pest management tactics can serve as one measure of the potential severity of risk to individual species. The “effective” period is well known for most pest management tactics. To be affected by a given tactic, larvae must be present during or immediately after this period. Although exact phenological data are not available for many of the lepidopteran species identified, it is often possible to determine which of the summer months the larvae of most species are known to be active.

The final step in our protocol was the inclusion of a relative imperilment or security status ranking for all species currently ranked by NatureServe (2001). These ranks are calculated through consultation of both published sources and a network of taxon specific expertise (NatureServe, 2001). The conservation rank of a species known or assumed to exist within a jurisdiction is designated by a whole number from 1 to 5, preceded by G (Global) or N (National). The ranks have the following meaning: 1 = critically imperiled; 2 = imperiled; 3 = vulnerable to extirpation or extinction; 4 = apparently secure; and 5 = demonstrably widespread, abundant, and secure. G1, for example, indicates critical imperilment on a range-wide basis while N1 indicates critical imperilment within the United States. These rankings provide a measure of which potentially affected species should be of particular concern.

Global and national ranks for Lepidoptera identified in our study as being associated with maize were compared with ranks of all the lepidopteran species (across all habitats) from the NatureServe database (NatureServe, 2001). Species with a rank range were assigned the lower rank. For example, a species ranked as G3G4 were assigned a rank of G3 for this analysis. Comparisons were analyzed with the two-tailed Fisher’s exact chi-square test, PROC FREQ (SAS Institute, 1996).

ACKNOWLEDGEMENTS

The authors wish to thank Catherine Day, Megan Edlund, Melissa Jensen, Stephanie Johnson, Luisa Perez, and Diane Tran for their assistance with gathering and collating data for the database. We also wish to thank Robert Dirig for his helpful early comments on lepidopteran species and their host plants and Richard Hoebeke for his help with deciphering nomenclature. The manuscript was greatly improved by editorial input from Leslie Allee. Data on conservation ranks was provided with permission and assistance from NatureServe: Copyright© 2001 NatureServe, 1101 Wilson Boulevard, 15th Floor, Arlington, Virginia 22209, USA. All Rights Reserved.

Received October 8, 2002; accepted July 15, 2003.

Appendix 1.

Plants associated with maize that are potential hosts of lepidopteran species.

Plant Number	Plant Common Name	Plant Scientific Name	Plant Family	Abundance	Weed Reference
1	Tumble piweed	<i>Amaranthus albus</i>	Amaranthaceae	Common	1
2	Sandhills amaranth	<i>Amaranthus arenicola</i>	Amaranthaceae	Rare	1
3	Prostrate pigweed	<i>Amaranthus graecizans</i>	Amaranthaceae	Rare	-
4	Palmer amaranth	<i>Amaranthus palmeri</i>	Amaranthaceae	Common	1
5	Red root pigweed	<i>Amaranthus retroflexus</i>	Amaranthaceae	Abundant	2
6	Common waterhemp	<i>Amaranthus rudis</i>	Amaranthaceae	Abundant	-
7	Spiny amaranth	<i>Amaranthus spinosus</i>	Amaranthaceae	Rare	-
8	Wild carrot	<i>Daucus carota</i>	Apiaceae	Rare	-
9	Hemp dogbane	<i>Apocynum cannabinum</i>	Apocynaceae	Common	2
10	Common milkweed	<i>Asclepias syriaca</i>	Asclepiadaceae	Common	2
11	Honeyvine milkweed	<i>Cynanchum laeve</i>	Asclepiadaceae	Common	-
12	Black swallow-wort	<i>Vincetoxicum nigrum</i>	Asclepiadaceae	Common	-
13	Common ragweed	<i>Ambrosia artemisiifolia</i>	Asteraceae	Abundant	-
14	Lanceleaf ragweed	<i>Ambrosia bidentata</i>	Asteraceae	Rare	-
15	Western ragweed	<i>Ambrosia psilostachya</i>	Asteraceae	Rare	-
16	Giant ragweed	<i>Ambrosia trifida</i>	Asteraceae	Abundant	-
17	Common burdock	<i>Arctium minus</i>	Asteraceae	Rare	-
18	Musk thistle	<i>Carduus nutans</i>	Asteraceae	Rare	-
19	Tall thistle	<i>Cirsium altissimum</i>	Asteraceae	Rare	-
20	Canada thistle	<i>Cirsium arvense</i>	Asteraceae	Common	2
21	Bull thistle	<i>Cirsium vulgare</i>	Asteraceae	Rare	-
22	Horseweed	<i>Conyza canadensis</i>	Asteraceae	Common	-
23	Rough fleabane	<i>Erigeron strigosus</i>	Asteraceae	Rare	-
24	Small flower galinsoga	<i>Galinsoga parviflora</i>	Asteraceae	Rare	-
25	Common sunflower	<i>Helianthus annuus</i>	Asteraceae	Abundant	2
26	Sawtooth sunflower	<i>Helianthus grosseserratus</i>	Asteraceae	Rare	-
27	Jerusalem artichoke	<i>Helianthus tuberosus</i>	Asteraceae	Common	-
28	Marsh elder	<i>Iva xanthifolia</i>	Asteraceae	Rare	3
29	Gray goldenrod	<i>Solidago nemoralis</i>	Asteraceae	Rare	-
30	Perennial sowthistle	<i>Sonchus arvensis</i>	Asteraceae	Rare	-
31	Dandelion	<i>Taraxacum officinale</i>	Asteraceae	Common	-
32	Common cocklebur	<i>Xanthium strumarium</i>	Asteraceae	Abundant	2
33	Trumpet creeper	<i>Campsis radicans</i>	Bignoniaceae	Rare	2
34	Yellow rocket	<i>Barbarea vulgaris</i>	Brassicaceae	Common	-
35	Indian mustard	<i>Brassica juncea</i>	Brassicaceae	Common	-
36	Wild mustard	<i>Brassica kaber</i>	Brassicaceae	Common	-
37	Black mustard	<i>Brassica nigra</i>	Brassicaceae	Rare	-
38	Shepherd's purse	<i>Capsella bursa-pastoris</i>	Brassicaceae	Common	-
39	Blue mustard	<i>Chorispora tenella</i>	Brassicaceae	Common	-
40	Field pepperweed	<i>Lepidium campestre</i>	Brassicaceae	Common	-
41	Tallhedge mustard	<i>Sisymbrium loeselii</i>	Brassicaceae	Common	-
42	Field pennycress	<i>Thlaspi arvense</i>	Brassicaceae	Common	-
43	Marijuana	<i>Cannabis sativa</i>	Cannabaceae	Common	-
44	Corn cockle	<i>Agrostemma githago</i>	Caryophyllaceae	Rare	-
45	Mouse-ear chickweed	<i>Cerastium vulgatum</i>	Caryophyllaceae	Rare	-
46	Bouncingbet	<i>Saponaria officinalis</i>	Caryophyllaceae	Rare	-
47	White cockle	<i>Silene alba</i>	Caryophyllaceae	Rare	-
48	Common chickweed	<i>Stellaria media</i>	Caryophyllaceae	Common	-
49	Spreading orach	<i>Atriplex subspicata</i>	Chenopodiaceae	Rare	-
50	Common lambsquarter	<i>Chenopodium album</i>	Chenopodiaceae	Abundant	2, 4
51	Mapleleaf goosefoot	<i>Chenopodium simplex</i>	Chenopodiaceae	Rare	-
52	Kochia	<i>Kochia scoparia</i>	Chenopodiaceae	Common	-
53	Rusian thistle	<i>Salsola iberi ca</i>	Chenopodiaceae	Common	3
54	Hedge bindweed	<i>Calystegia sepium</i>	Convolvulaceae	Common	-
55	Field bindweed	<i>Convolvulus arvensis</i>	Convolvulaceae	Common	-
56	Bindweeds	<i>Convolvulus spp.</i>	Convolvulaceae	Common	-
57	Ivyleaf morning glory	<i>Ipomoea hederacea</i>	Convolvulaceae	Common	-
58	Purple morning glory	<i>Ipomoea purpurea</i>	Convolvulaceae	Common	1

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Appendix 1.
Continued.

Plant Number	Plant Common Name	Plant Scientific Name	Plant Family	Abundance	Weed Reference
59	Buffalo gourd	<i>Cucurbita foetidissima</i>	Cucurbitaceae	Rare	-
60	Wild cucumber	<i>Echinocystis lobata</i>	Cucurbitaceae	Common	-
61	Bur cucumber	<i>Sicyos angulatus</i>	Cucurbitaceae	Common	-
62	Yellow nutsedge	<i>Cyperus rotundus</i>	Cyperaceae	Abundant	1
63	Field horsetail	<i>Equisetum arvense</i>	Equisetaceae	Rare	-
64	Virginia copperleaf	<i>Acalypha virginica</i>	Euphorbiaceae	Rare	-
65	Toothed spurge	<i>Euphorbia dentata</i>	Euphorbiaceae	Common	3
66	Spotted spurge	<i>Euphorbia maculata</i>	Euphorbiaceae	Rare	-
67	Alfalfa	<i>Medicago sativa</i>	Fabaceae	Rare	-
68	White clover	<i>Trifolium repens</i>	Fabaceae	Rare	-
69	Carolina geranium	<i>Geranium carolinianum</i>	Geraniaceae	Rare	-
70	Wild onion	<i>Allium canadense</i>	Liliaceae	Rare	-
71	Wild garlic	<i>Allium vineale</i>	Liliaceae	Rare	-
72	Velvetleaf	<i>Abutilon theophrasti</i>	Malvaceae	Abundant	2
73	Venice mallow	<i>Hibiscus trionum</i>	Malvaceae	Common	3
74	Common mallow	<i>Malva neglecta</i>	Malvaceae	Rare	3
75	Prickly sida	<i>Sida spinosa</i>	Malvaceae	Common	-
76	Carpetweed	<i>Mollugo verticillata</i>	Molluginaceae	Rare	-
77	Wild four-o'clock	<i>Mirabilis nyctaginea</i>	Nyctaginaceae	Rare	-
78	Evening primrose	<i>Oenothera biennis</i>	Onagraceae	Rare	-
79	Yellow woodsorrel	<i>Oxalis stricta</i>	Oxalidaceae	Rare	-
80	Common pokeweed	<i>Phytolacca americana</i>	Phytolaccaceae	Rare	-
81	Buckhorn plantain	<i>Plantago lanceolata</i>	Plantaginaceae	Rare	-
82	Quackgrass	<i>Agropyron repens</i>	Poaceae	Abundant	-
83	Wild oat	<i>Avena fatua</i>	Poaceae	Rare	3
84	Signalgrass	<i>Brachiaria platyphylla</i>	Poaceae	Rare	1
85	Japanese brome	<i>Bromus japonicus</i>	Poaceae	Rare	-
86	Cheatgrass	<i>Bromus secalinus</i>	Poaceae	Rare	-
87	Downy brome	<i>Bromus tectorum</i>	Poaceae	Rare	-
88	Longspine sandbur	<i>Cenchrus longispinus</i>	Poaceae	Common	3
89	Bermudagrass	<i>Cynodon dactylon</i>	Poaceae	Rare	1
90	Orchardgrass	<i>Dactylis glomerata</i>	Poaceae	Rare	-
91	Smooth crabgrass	<i>Digitaria ischaemum</i>	Poaceae	Common	1
92	Large crabgrass	<i>Digitaria sanguinalis</i>	Poaceae	Common	1
93	Barnyardgrass	<i>Echinochloa crus-galli</i>	Poaceae	Common	3
94	Goosegrass	<i>Eleusine indica</i>	Poaceae	Rare	-
95	Stinkgrass	<i>Eragrostris cilianensis</i>	Poaceae	Rare	3
96	Woolly cupgrass	<i>Eriochloa villosa</i>	Poaceae	Common	-
97	Tall fescue	<i>Festuca arundinacea</i>	Poaceae	Rare	-
98	Wirestem muhly	<i>Muhlenbergia frondosa</i>	Poaceae	Common	-
99	Witchgrass	<i>Panicum capillare</i>	Poaceae	Common	3
100	Fall panicum	<i>Panicum dichotomiflorum</i>	Poaceae	Abundant	-
101	Wild-proso millet	<i>Panicum miliaceum</i>	Poaceae	Rare	3
102	Texas panicum	<i>Panicum texanum</i>	Poaceae	Rare	1
103	Giant foxtail	<i>Setaria faberi</i>	Poaceae	Abundant	-
104	Yellow foxtail	<i>Setaria glauca</i>	Poaceae	Abundant	3
105	Bristly foxtail	<i>Setaria verticillata</i>	Poaceae	Rare	-
106	Green foxtail	<i>Setaria viridis</i>	Poaceae	Abundant	3
107	Shattercane	<i>Sorghum bicolor</i>	Poaceae	Common	3
108	Johnsongrass	<i>Sorghum halepense</i>	Poaceae	Common	2
109	Corn	<i>Zea mays</i>	Poaceae	Abundant	-
110	Alpine smartweed	<i>Polygonum viviparum</i>	Polygonaceae	Rare	-
111	Swamp smartweed	<i>Polygonum coccineum</i>	Polygonaceae	Common	-
112	Wild buckwheat	<i>Polygonum convolvulus</i>	Polygonaceae	Rare	3
113	Pennsylvania smartweed	<i>Polygonum pennsylvanicum</i>	Polygonaceae	Abundant	2
114	Red sorrel	<i>Rumex acetosella</i>	Polygonaceae	Rare	-
115	Pale dock	<i>Rumex altissimus</i>	Polygonaceae	Rare	-
116	Curly dock	<i>Rumex crispus</i>	Polygonaceae	Rare	-

Appendix 1.
Continued.

Plant Number	Plant Common Name	Plant Scientific Name	Plant Family	Abundance	Weed Reference
117	Broadleaf dock	<i>Rumex obtusifolius</i>	Polygonaceae	Rare	-
118	Common purslane	<i>Portulaca oleracea</i>	Portulacaceae	Rare	3
119	Rough cinquefoil	<i>Potentilla norvegica</i>	Rosaceae	Rare	-
120	Sulphur cinquefoil	<i>Potentilla recta</i>	Rosaceae	Rare	-
121	Wild blackberry	<i>Rubus allegheniensis</i>	Rosaceae	Rare	4
122	Catchweed bed straw	<i>Galium aparine</i>	Rubiaceae	Rare	-
123	Common mullein	<i>Verbascum thapsus</i>	Scrophulariaceae	Rare	-
124	Field speedwell	<i>Veronica agrestis</i>	Scrophulariaceae	Rare	-
125	Jimsonweed	<i>Datura stramonium</i>	Solanaceae	Common	-
126	Clammy groundcherry	<i>Physalis heterophylla</i>	Solanaceae	Common	-
127	Virginia groundcherry	<i>Physalis virginiana</i>	Solanaceae	Common	-
128	Horse nettle	<i>Solanum carolinense</i>	Solanaceae	Common	1
129	Eastern blacknightshade	<i>Solanum ptycanthum</i>	Solanaceae	Abundant	-
130	Buffalo bur	<i>Solanum rostratum</i>	Solanaceae	Common	2
131	Hairy nightshade	<i>Solanum sarrachoides</i>	Solanaceae	Rare	3
132	Common cattail	<i>Typha latifolia</i>	Typhaceae	Rare	-

Weed codes are from the following references: 1 = Webster and Cobble, 1997; 2 = Wax et al., 1981; 3 = Schweizer et al., 1998; and 4 = Glenn et al., 1997.

Appendix 2.

Lepidopteran species reported to feed as larva on plants that occur in and around maize fields.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Aegeridae	<i>Albuna pyramidalis rubescens</i>	-	-	-	-	78	2	-	-
Agarastidae	<i>Euscirrhopterus gloveri</i>	-	-	-	-	118	13	-	-
Amatidae	<i>Ctenucha virginica</i>	virginia ctenucha	Y	Y	N	93, 99	13	-	-
Arctiidae	<i>Apantesis figurata</i>	-	-	-	-	67	13	-	-
Arctiidae	<i>Apantesis arge</i>	-	-	-	-	81	13	-	-
Arctiidae	<i>Apantesis ornata</i>	-	-	-	-	50	13	-	-
Arctiidae	<i>Apantesis parthenice</i>	-	N	?	Y	50	13	-	-
Arctiidae	<i>Arachnis picta</i>	painted arachnis	-	-	-	67	13	-	-
Arctiidae	<i>Arctia caja</i>	great tiger moth	Y	Y	Y	50	13	G5	-
Arctiidae	<i>Estigmene acrea</i>	saltmarsh moth	Y	Y	Y	7	13	G5	-
Arctiidae	<i>Euchaetias egle</i>	milkweed tussock moth	Y	Y	Y	11	10	G5	-
Arctiidae	<i>Haploa lecontei</i>	Leconte's haploa	Y	Y	Y	121	13	G5	-
Arctiidae	<i>Holomelina aurantiaca</i>	-	Y	Y	Y	31, 50, 109	13	G5	-
Arctiidae	<i>Hyphantria cunea</i>	fall webworm	Y	Y	Y	67	14	G5	-
Arctiidae	<i>Pyrrharctia isabella</i>	banded woollybear	Y	N	Y	82, 25, 121	13	-	-
Arctiidae	<i>Spilosoma vagans</i>	-	-	-	-	50	13	-	-
Arctiidae	<i>Spilosoma virginica</i>	yellow woolly bear moth	Y	N	Y	16, 25, 50, 58, 67, 112, 121, 130	13	G5	N5
Citheroniidae	<i>Anisota senatoria</i>	orangestriped oak-worm	Y	Y	Y	121	13	G5	N5
Geometridae	<i>Catopyrra coloraria</i>	-	Y	Y	N	121	3	G4	-
Geometridae	<i>Cepphis decoloraria</i>	-	Y	Y	Y	121	3	G5	-

Lepidopteran species associated with maize

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Geometridae	<i>Chlorochlamys chloroleucaria</i>	blackberry looper moth	Y	Y	Y	121	13	–	–
Geometridae	<i>Cingilia catenaria</i>	chainspotted geometer	N	N	N	53	13	–	–
Geometridae	<i>Dysstroma citrata</i>	dark marbled carpet	N	Y	Y	121	13	G5	–
Geometridae	<i>Hydria undulata</i>	scallop-shell moth	N	Y	N	121	13	–	–
Geometridae	<i>Phigalia titea</i>	the half-wing	N	N	N	121	13	–	–
Geometridae	<i>Scopula inductata</i>	soft-lined wave	Y	Y	Y	16	13	–	–
Geometridae	<i>Synchlora aerea</i>	wavy-lined emerald	Y	Y	Y	121	13	G5	–
Geometridae	<i>Xanthorhoe lacustrata</i>	toothed brown carpet	Y	Y	Y	121	13	–	–
Hesperiidae	<i>Amblyscirtes hegon</i>	pepper and salt skipper	Y	Y	Y	107	13	G5	N5
Hesperiidae	<i>Amblyscirtes nysa</i>	nysa roadside skipper	Y	Y	Y	106	5	G5	N5
Hesperiidae	<i>Amblyscirtes vialis</i>	roadside skipper	Y	Y	Y	89	8	G5	N5
Hesperiidae	<i>Atalopedes campestris</i>	satchem	Y	Y	Y	89	8	G5	N5
Hesperiidae	<i>Carterocephalus palaemon</i>	checked skipper butterfly	Y	Y	Y	82, 92	13	G5	N5
Hesperiidae	<i>Copaeodes minimus</i>	southern skipperling	Y	Y	Y	89	17	G5	N5
Hesperiidae	<i>Copaeodes minimus aurantiaca</i>	orange skipperling	Y	Y	Y	92, 89	17,13	G5	
Hesperiidae	<i>Erimnys funeralis</i>	funeral dusky wing	Y	Y	Y	67	13	G5	N5
Hesperiidae	<i>Erynnis lucilius</i>	columbine dusky wing	Y	Y	Y	78, 50	17, 13	G4	N4
Hesperiidae	<i>Erynnis martialis</i>	mottled duskywing	Y	Y	Y	5, 6	13	G3G4	N3N4
Hesperiidae	<i>Hesperia sassacus</i>	indian skipper	Y	Y	N	92	5	G5	N5
Hesperiidae	<i>Hylephila phyleus</i>	fiery skipper	Y	Y	Y	89	9	G5	N5
Hesperiidae	<i>Lerema accius</i>	clouded skipper	Y	Y	Y	99, 109	11, 9	G5	N5
Hesperiidae	<i>Lerodea eufala</i>	eufala skipper	Y	Y	Y	108	5	G5	N5
Hesperiidae	<i>Panoquina errans</i>	wandering skipper	N	Y	Y	89	7	–	–
Hesperiidae	<i>Pholisora catullus</i>	common sooty wing	Y	Y	Y	3, 50, 5	6, 9, 5	G5	N5
Hesperiidae	<i>Poanes melane</i>	umber skipper	Y	Y	Y	89, 91	13	G5	N5
Hesperiidae	<i>Polites mystic</i>	long dash	Y	Y	Y	82	11	G5	N5
Hesperiidae	<i>Polites sabuleti</i>	sandhill skipper	–	–	–	89	13	G5	N5
Hesperiidae	<i>Polites themistocles</i>	tawny edged skipper	Y	Y	Y	82	13	G5	N5
Hesperiidae	<i>Polites vibex</i>	whirlabout	Y	Y	Y	89	8	G5	N5
Hesperiidae	<i>Pyrgus communis</i>	checkered skipper	Y	Y	Y	50, 73	8, 11	G5	N5
Hesperiidae	<i>Pyrgus syrichtus</i>	tropical checkered skipper	Y	Y	Y	74	9	G5	–
Hesperiidae	<i>Staphylus ceos</i>	golden-headed sooty-wing	Y	Y	Y	51	7	G5	N4
Hesperiidae	<i>Staphylus hayhurstii</i>	southern sooty wing	Y	Y	Y	50	8	G5	N5
Hesperiidae	<i>Staphylus mazans</i>	southern scalloped sooty wing	Y	Y	Y	5	5	G5	N3N4
Hesperiidae	<i>Thorybes bathyllus</i>	southern cloudy wing	N	N	N	68	17	G5	N5
Hesperiidae	<i>Thorybes pylades</i>	northern cloudy wing	Y	Y	Y	67, 68	8, 13	G5	N5

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Hesperiidae	<i>Urbanus simplicius</i>	plain longtail	–	–	–	89	7	G5	–
Hesperiidae	<i>Wallengrenia otho</i>	–	–	–	–	92	13	G5	–
Hesperiidae	<i>Wallengrenia otho egeremet</i>	broken-dash	–	–	–	92	1	G5	N5
Lasiocampidae	<i>Malacosoma californica</i>	western tent caterpillar	Y	Y	Y	121	13	–	–
Liparidae	<i>Nygmia phaeorrhoea</i>	brown-tail moth	?	?	?	121	13	–	–
Liparidae	<i>Orgyia leucostigma</i>	–	?	?	?	33, 50	13	G5	–
Lycaenidae	<i>Brephidium exile</i>	western pigmy blue	Y	Y	Y	50, 5	5, 9	G5	N5
Lycaenidae	<i>Everes comyntas</i>	eastern tailed blue	Y	Y	Y	68	5	–	–
Lycaenidae	<i>Everes comyntas</i>	eastern tailed blue	Y	Y	Y	67, 16	8, 13	G5	N5
Lycaenidae	<i>Gaeides xanthoides</i>	great grey copper	Y	Y	Y	116, 117	9	–	–
Lycaenidae	<i>Hemiargus gyas</i>	–	–	–	–	67	13	–	–
Lycaenidae	<i>Leptotes marina</i>	marine blue	–	–	–	67	13	G5	N5
Lycaenidae	<i>Lycaeides melissa</i>	orange-bordered blue	Y	Y	Y	67	9	G5	N5
Lycaenidae	<i>Lycaeides melissa samuelis</i>	karner blue	Y	Y	N	67	12	G5	N2
Lycaenidae	<i>Lycaena helloides</i>	purplish copper	Y	Y	Y	114	17	G5	N5
Lycaenidae	<i>Lycaena hyllus</i>	bronze copper	Y	Y	Y	116	11	G5	N5
Lycaenidae	<i>Lycaena phlaeas</i>	American copper	Y	Y	Y	114, 116	11	G5	N5
Lycaenidae	<i>Plebejus saepiolus</i>	greenish blue	Y	Y	Y	115, 116	5	G5	N5
Noctuidae	<i>Acronicta impressa</i>	–	–	–	–	121	13	–	–
Noctuidae	<i>Acronicta longa</i>	long-winged dagger moth	Y	Y	Y	121	13	–	–
Noctuidae	<i>Acronicta oblongata</i>	smear-dagger moth	Y	Y	Y	121, 132	13	G5	N5
Noctuidae	<i>Acronicta spingera</i>	nondescript dagger moth	Y	Y	Y	121	13	G4	–
Noctuidae	<i>Actebia fennica</i>	black army cutworm	N	Y	Y	121, 123	13	–	–
Noctuidae	<i>Agrotis gladiaria</i>	swordsman dart	N	N	?	121	13	G5	–
Noctuidae	<i>Agrotis ipsilon</i>	black cutworm	Y	Y	Y	37	13	G5	–
Noctuidae	<i>Agrotis orthogonia</i>	pale western cutworm	–	–	–	20, 37, 50	13	–	–
Noctuidae	<i>Agrotis vetusta</i>	old man dart	N	Y	Y	123	13	–	–
Noctuidae	<i>Anicla infecta</i>	green clover worm moth	Y	Y	Y	92	13	G5	–
Noctuidae	<i>Anomis erosa</i>	yellow scallop moth	N	N	Y	72	13	G5	–
Noctuidae	<i>Anticarsia gemmatilis</i>	velvetbean caterpillar	N	N	N	67	13	G5	–
Noctuidae	<i>Archana oblonga</i>	oblong sedge borer moth	N	Y	Y	132	13	G5	–
Noctuidae	<i>Autographa californica</i>	alfalfa looper	–	–	–	67	13	–	–
Noctuidae	<i>Autographa precatonensis</i>	common looper moth	Y	Y	Y	50	13	G5	–
Noctuidae	<i>Bellura densa</i>	–	–	–	–	132	13	–	–
Noctuidae	<i>Bellura obliqua</i>	–	–	–	–	132	13	–	–
Noctuidae	<i>Caenurgina erechthea</i>	forage looper	Y	Y	Y	16, 67	13	G5	–
Noctuidae	<i>Cercyonis latipes</i>	small mocus	Y	Y	Y	92, 109	13	–	–

Lepidopteran species associated with maize

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Noctuidae	<i>Copablepharon viridisparsum</i>	–	–	–	–	37	13	–	–
Noctuidae	<i>Crymodes devastator</i>	glassy cutworm moth	Y	Y	Y	67	13	–	–
Noctuidae	<i>Dargida procincta</i>	–	–	–	–	82	13	–	–
Noctuidae	<i>Erastria carneola</i>	–	Y	Y	Y	116	13	–	–
Noctuidae	<i>Euxoa auxiliaris</i>	army cutworm	–	–	–	37	13	–	–
Noctuidae	<i>Euxoa costata</i>	–	–	–	–	53	13	–	–
Noctuidae	<i>Euxoa divergens</i>	divergent dart	Y	Y	N	67	13	G4	–
Noctuidae	<i>Euxoa messoria</i>	reaper dart	N	N	Y	25	16	–	–
Noctuidae	<i>Euxoa pallipennis</i>	–	–	–	–	53	13	–	–
Noctuidae	<i>Euxoa pleuritica</i>	–	?	?	?	118	3	G4	–
Noctuidae	<i>Euxoa scandens</i>	white cutworm	Y	Y	N	121	13	G5	–
Noctuidae	<i>Euxoa tristicula</i>	–	N	Y	N	121	3	G4	–
Noctuidae	<i>Feltia subterranea</i>	granulate cutworm	N	Y	Y	31, 6	15, 13	–	–
Noctuidae	<i>Heliothis obsoleta</i>	cotton boll-worm	?	?	Y	32, 50, 58, 67, 73, 91, 107	13	–	–
Noctuidae	<i>Heliothis phloxiphagus</i>	–	–	–	–	67	13	G5	–
Noctuidae	<i>Heliothis virescens</i>	tobacco budworm	Y	Y	Y	67, 116	13	G5	–
Noctuidae	<i>Hyppa xylinoides</i>	common hyppa	Y	Y	Y	31, 50	13	–	–
Noctuidae	<i>Lacinipolia lorea</i>	bridled arches	Y	Y	Y	67	13	–	–
Noctuidae	<i>Lacinipolia olivacea</i>	olive arches	y	Y	Y	81	13	–	–
Noctuidae	<i>Lacinipolia renigera</i>	bristly cutworm	Y	Y	Y	67, 81	13	G5	–
Noctuidae	<i>Leucania latiuscula</i>	–	–	–	–	107, 109	13	–	–
Noctuidae	<i>Leucania multilinea</i>	many-lined wainscot	Y	Y	Y	107	13	G5	–
Noctuidae	<i>Leucania pseudargyria guenee</i>	false wainscot	Y	Y	Y	132	13	G5	–
Noctuidae	<i>Leuconycta diptheroides</i>	green leuconycta	Y	Y	Y	29	10	G5	–
Noctuidae	<i>Luperina stipata</i>	–	–	–	–	104	13	G4	–
Noctuidae	<i>Mamestra configurata</i>	bertha armyworm	–	–	–	67	13	–	–
Noctuidae	<i>Melanchra picta</i>	painted mamestra	–	–	–	8, 9, 67	13	G4	–
Noctuidae	<i>Nola sorghiella</i>	–	Y	Y	Y	107	13	–	–
Noctuidae	<i>Ogdoconta cinereola</i>	common pinkband	Y	Y	Y	16, 13, 25	16, 3	G5	–
Noctuidae	<i>Palthis angulais</i>	dark-spotted palthis	Y	Y	Y	121	13	G5	–
Noctuidae	<i>Papaipema nebris</i>	stalk borer	N	N	N	123	13	G5	N5
Noctuidae	<i>Papaipema arctivorens</i>	–	–	–	–	20	13	G5	N5
Noctuidae	<i>Papaipema arctivorens hampson</i>	–	–	–	–	21	13	–	–
Noctuidae	<i>Papaipema cataphracta</i>	burdock borer	N	N	N	109, 121	13	G5	N5
Noctuidae	<i>Papaipema nebris</i>	stalk borer	N	N	N	13, 16, 20, 32, 50, 121	13	G5	N5
Noctuidae	<i>Papaipema necopina</i>	–	–	–	–	26	13	G4	N4
Noctuidae	<i>Papaipema rutila</i>	–	–	–	–	16	13	G4	N4
Noctuidae	<i>Peridroma margaritosa</i>	pearly underwing	Y	Y	Y	7, 81, 109, 118, 121, 125	13	–	–

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Noctuidae	<i>Phosphila turbulenta</i>	turbulent phosphila	Y	Y	Y	128	13	G5	–
Noctuidae	<i>Plagiomimicus pityochromus</i>	black-barred brown	N	N	Y	16	13	–	–
Noctuidae	<i>Plathypena scabra</i>	green clover worm moth	Y	Y	?	67, 8, 16, 91	10, 13	G5	–
Noctuidae	<i>Polia atlantica</i>	–	–	–	–	67	13	–	–
Noctuidae	<i>Polia grandis</i>	–	Y	Y	Y	50	13	–	–
Noctuidae	<i>Polia legitima</i>	striped garden caterpillar	Y	Y	Y	92, 121	13	–	–
Noctuidae	<i>Protorthodes incincta</i>	–	–	–	–	67	13	–	–
Noctuidae	<i>Pseudaletia unipuncta</i>	white-speck	Y	Y	Y	6, 16, 82, 89, 92, 101, 107	13	G5	N5
Noctuidae	<i>Pseudorthodes irrorata</i>	–	–	–	–	81	13	–	–
Noctuidae	<i>Psychomorpha epimenis</i>	grapevine epimenis	Y	N	N	33	13	G5	–
Noctuidae	<i>Pyrrhia umbra</i>	bordered sallow	Y	Y	Y	113, 121	13	–	–
Noctuidae	<i>Schinia florida</i>	primrose moth	Y	Y	Y	78	4	–	–
Noctuidae	<i>Schinia marginata</i>	–	–	–	–	13	13	–	–
Noctuidae	<i>Schinia rivulosa</i>	–	Y	Y	Y	13	4	G5	–
Noctuidae	<i>Schinia thoreauii</i>	Thoreau's flower moth	Y	Y	Y	16	13	–	–
Noctuidae	<i>Scotogramma trifolii</i>	clover cutworm	Y	Y	Y	50, 118	13	–	–
Noctuidae	<i>Simyra henrici</i>	Henry's marsh moth	Y	Y	Y	132	13	G5	–
Noctuidae	<i>Spodoptera dolichos</i>	–	Y	N	Y	125	3	G5	–
Noctuidae	<i>Spodoptera eridania</i>	southern army worm	–	–	–	7, 91, 92	13	G5	–
Noctuidae	<i>Spodoptera exigua</i>	beet army worm	–	–	–	5, 25, 50, 67	13	G5	–
Noctuidae	<i>Spodoptera frugiperda</i>	fall army worm	N	Y	Y	5, 32, 50, 56, 62, 67, 91, 92, 101, 102, 107	13	G5	–
Noctuidae	<i>spodoptera ornithogalli</i>	cotton cutworm	–	–	–	5, 7, 22, 50, 58, 67, 81, 121, 125, 128	13	G5	–
Noctuidae	<i>Spodoptera praefica</i>	western yellowstriped armyworm	–	–	–	50, 58, 67, 107, 121	13	–	–
Noctuidae	<i>Stibadium spumosum</i>	frothy moth	N	N	Y	25	3	–	–
Noctuidae	<i>Tarachidia candefacta</i>	olive-shaded bird-dropping moth	Y	Y	Y	13	13	G5	–
Noctuidae	<i>Tarachidia erastriodes</i>	small bird-dropping moth	Y	Y	Y	13	13	G5	–
Noctuidae	<i>Trichoplusia ni</i>	cabagge looper	–	–	–	37, 50	13	–	–
Notodontidae	<i>Datana ministra</i>	yellownecked caterpillar	Y	N	N	121	13	G5	–
Notodontidae	<i>Heterocampa guttivitta</i>	maple prominent	Y	Y	Y	121	13	G5	–
Notodontidae	<i>Schizura concinna</i>	red-humped caterpillar moth	Y	Y	Y	121	13	–	–
Notodontidae	<i>Schizura ipomoeae</i>	morning-glory prominent	Y	Y	Y	56, 121	13	G5	–

Lepidopteran species associated with maize

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Notodontidae	<i>Schizura unicornis</i>	unicorn caterpillar moth	Y	Y	Y	121	13	–	–
Nymphalidae	<i>Charidryas gorgone</i>	gorgone crescent spot	Y	Y	N	16	9	–	–
Nymphalidae	<i>Charidryas nycteis</i>	silvery checkerspot	–	–	–	22	13	G5	–
Nymphalidae	<i>Chlosyne gorgone</i>	great plains checkerspot	Y	Y	Y	25	11	G5	N5
Nymphalidae	<i>Chlosyne lacinia</i>	bordered patch	Y	Y	Y	25, 16	10, 7	G5	N5
Nymphalidae	<i>Chlosyne lacinia adjatrix</i>	bordered patch	Y	Y	Y	16	5	–	–
Nymphalidae	<i>Chlosyne nycteis</i>	streamside checkerspot	Y	Y	Y	25	11	G5	N5
Nymphalidae	<i>Chlosyne palla</i>	northern checkerspot	Y	Y	Y	23	7	G5	N5
Nymphalidae	<i>Chlosyne whitneyi</i>	rockslide checkerspot	?	Y	Y	23	7	G4G5	N4
Nymphalidae	<i>Cylopsis gemma</i>	gemmed satyr	Y	Y	Y	89	8	G5	N5
Nymphalidae	<i>Danaus gilippus</i>	queen butterfly	N	Y	Y	11	17	G5	N5
Nymphalidae	<i>Danaus plexippus</i>	monarch butterfly	Y	Y	Y	11	7	G4	N2N3
Nymphalidae	<i>Euphydryas gillettii</i>	yellowstone checkerspot	Y	Y	Y	124	7	–	–
Nymphalidae	<i>Euphydryas phaeton</i>	the baltimore	Y	Y	Y	132	13	G4	N4
Nymphalidae	<i>Euptoieta claudia</i>	variegated fritillary	Y	Y	Y	118	11	G5	N5
Nymphalidae	<i>Junonia coenia</i>	common buckeye	Y	Y	Y	81	7	–	–
Nymphalidae	<i>Megisto rubricata</i>	red satyr	Y	Y	Y	89	17	G5	N5
Nymphalidae	<i>Nymphalis californica</i>	california tortoise shell	Y	Y	Y	67	13	G5	N5
Nymphalidae	<i>Nymphalis milberti</i>	Milbert's tortoise shell	N	Y	Y	25	13	G5	N5
Nymphalidae	<i>Occidryas taylori</i>	–	–	–	–	81	13	–	–
Nymphalidae	<i>Phyciodes pictus</i>	painted crescent	Y	Y	Y	67, 55	13, 17	G5	–
Nymphalidae	<i>Phyciodes tharos</i>	pearl crescent	Y	Y	Y	23	7	G5	N5
Nymphalidae	<i>Polygonia comma</i>	comma butterfly	–	–	–	13, 16	13	G5	N5
Nymphalidae	<i>Polygonia gracilis</i>	graceful angle wing	–	–	–	16	13	G5	N5
Nymphalidae	<i>Polygonia interrogationis</i>	question mark	–	–	–	13, 16	13	G5	N5
Nymphalidae	<i>Proclissiana eunomia</i>	–	–	–	–	110	5	G5	–
Nymphalidae	<i>Proclissiana titania</i>	–	–	–	–	110	17	–	–
Nymphalidae	<i>Vanessa atalanta</i>	red admiral, alderman	Y	Y	Y	13, 16	13	G5	N5
Nymphalidae	<i>Vanessa cardui</i>	painted lady	Y	Y	Y	18, 21, 20, 50, 74	16, 11	G5	N5
Nymphalidae	<i>Vanessa virginiensis</i>	painted beauty	Y	Y	Y	20	13	G5	N5
Papilionidae	<i>Battus philenor</i>	pipevine swallowtail	Y	Y	Y	112	11	G5	N5
Papilionidae	<i>Papilio polyxenes</i>	black swallowtail	Y	Y	Y	8	9	G5	N5
Papilionidae	<i>Papilio zelicaon lucas</i>	anise swallowtail	Y	Y	N	8	13	G5	N5
Pieridae	<i>Anthocharis cethura</i>	desert orangetip	N	N	N	36	13	G4G5	N4N5
Pieridae	<i>Anthocharis midea</i>	falcate orangetip	N	N	N	34	9	G4G5	N4N5
Pieridae	<i>Anthocharis sara stella</i>	western orange tip	Y	Y	N	37	13	–	–
Pieridae	<i>Artogeia napi</i>	sharp-veined white	Y	Y	Y	37	13	G5	–

Appendix 2.
Continued.

Family	Species	Common name	Jn	Jl	Ag	Host plant code ¹	Plant utilization reference ²	Global rank	National rank
Pieridae	<i>Colias alexandra</i>	queen alexandra's sulphur	Y	Y	Y	68	17	G5	N5
Pieridae	<i>Colias eurytheme</i>	alphantha sulphur	Y	Y	Y	67	13	G5	N5
Pieridae	<i>Colias philodice</i>	clouded sulphur	Y	Y	?	68, 67	17, 5	G5	N5
Pieridae	<i>Falcapoca midea</i>	falcate orangetip	–	–	–	34, 38	6	–	–
Pieridae	<i>Nathalis iole</i>	dainty sulphur	Y	Y	Y	48	6	G5	N5
Pieridae	<i>Pieris rapae</i>	imported cabbageworm	Y	Y	Y	37	13	G5	Ne
Pieridae	<i>Pontia beckerii</i>	sagebrush white	Y	N	Y	37	9	G5	N5
Pieridae	<i>Pontia occidentalis</i>	western white	Y	Y	Y	37	7	G5	N5
Pieridae	<i>Pontra protodice</i>	checkered white	Y	Y	Y	22, 36, 38, 128	5, 13	–	–
Pieridae	<i>Zerene cesonia</i>	southern dogface	Y	Y	Y	67	8	G5	N5
Saturniidae	<i>Automeris io</i>	io moth	Y	Y	Y	121	13	G5	N5
Saturniidae	<i>Hemileuca nevadensis stretch</i>	Nevada buck moth	N	N	N	13	13	G5	N5
Saturniidae	<i>Hyalphora cecropia</i>	emperor	Y	N	N	121	3	–	–
Satyridae	<i>Neonympha phocion</i>	–	–	–	–	92	13	–	–
Satyridae	<i>Minois pegala</i>	blue-eyed grayling	–	–	–	83	13	G5	–
Sphingidae	<i>Agrius cingulata</i>	pink-spotted hawk moth	Y	Y	Y	125	13	–	–
Sphingidae	<i>Ceratonia undulosa</i>	waved sphinx	Y	Y	Y	33	13	G5	N5
Sphingidae	<i>Erinnyis ello</i>	ello sphinx	N	Y	Y	65	17	G4G5	N4
Sphingidae	<i>Hemaris diffinis</i>	snowberry clearwing	Y	Y	Y	9	17	G4G5	N5
Sphingidae	<i>Hyles gallii</i>	dark-veined deilephila	–	–	–	118	13	G5	–
Sphingidae	<i>Hyles lineata</i>	white-lined sphinx	Y	Y	Y	118	13	G5	N5
Sphingidae	<i>Manduca quinquemaculata</i>	five-spotted sphinx	Y	Y	Y	125	13	G5	–
Sphingidae	<i>Manduca rustica</i>	six-spotted sphinx	N	Y	Y	25	13	G5	–
Sphingidae	<i>Manduca sexta</i>	Carolina sphinx	Y	Y	Y	125, 128	13	G5	–
Sphingidae	<i>Paonias excaecata</i>	blind-eyed sphinx	Y	Y	Y	121	13	G5	N5
Sphingidae	<i>Paratrea plebeja</i>	plebian sphinx	Y	Y	Y	33	17	G5	N5
Sphingidae	<i>Proserpinus juanita</i>	green-banded day sphinx	Y	Y	Y	78	10	G4G5	N4N5
Thyatiridae	<i>Habrosyne scripta</i>	lettered habrosyne	Y	Y	Y	121	3	G5	–
Thyatiridae	<i>Haematopsis grataria</i>	chickweed geometer	Y	Y	Y	48	10	–	–
Zanolidae	<i>Apatelodes torrefacta</i>	spotted apatelodes	Y	Y	Y	121	13	G5	–

¹ Host plant codes from Appendix 1.

² Plant utilization codes are from the following references: 1 = Ebner, 1970; 2 = Engelhardt, 1946; 3 = Forbes, 1969; 4 = Hardwick, 1996; 5 = Howe, 1975; 6 = Klots, 1979; 7 = Opler, 1999; 8 = Opler and Krizek, 1984; 9 = Pyle, 1992; 10 = Richard and Heitzman, 1987; 11 = Scott, 1986; 12 = Shull, 1987; 13 = Tietz, 1972; 14 = Zhang, 1994; 15 = ipmwww.ncsu.edu/AG271/corn_sorghum/granulate_cutworm.htm; 16 = www.ext.nodak.edu/extpubs/plantsci/rowcrops/eb25w-6a.htm; 17 = <http://www.npwrc.usgs.gov/resource/distr/lepid/BFLYUSA/bflyusa.htm>.

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