Impact of Planting Dates on a Seed Maggot, *Neotephritis finalis* (Diptera: Tephritidae), and Sunflower Bud Moth (Lepidoptera: Tortricidae) Damage in Cultivated Sunflower

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ABSTRACT *Neotephritis finalis* (Loew) (Diptera: Tephritidae), and sunflower bud moth, *Suleima helianthana* (Riley) (Lepidoptera: Tortricidae) are major head-infesting insect pests of cultivated sunflower (*Helianthus annuus* L.). Planting date was evaluated as a cultural pest management strategy for control of *N. finalis* and *S. helianthana* in several production regions of North Dakota during 2009 and 2010. Results of the nine site-year study revealed that late planting date (early to mid-June) reduced damage ratings and percentage of damaged heads for *N. finalis* compared with early planting dates (mid- to late May). Visual observations of adult *N. finalis* found that the majority of flies were found in the early planted sunflower (78.2%) compared with the late planted sunflower (21.8%). Late planting date also reduced the percentage of *S. helianthana* damaged heads compared with early planting dates. Yield losses were reduced with late planting date when populations of *N. finalis* and *S. helianthana* were high enough to cause damage. Results of this study showed that delayed planting is an effective integrated pest management strategy that can reduce head damage caused by *N. finalis* and *S. helianthana* and mitigate yield losses.

KEY WORDS sunflower, *Neotephritis finalis*, sunflower bud moth, *Suleima helianthana*, planting date

Sunflower (*Helianthus annuus* L.) is one of only a very few domesticated crops native to North America. It is commercially cultivated on a large scale in the United States in the northern Great Plains (North Dakota and South Dakota) and the southern High Plains (western Nebraska and Kansas plus areas of Colorado and Texas) (Putt 1997). In 2009, North Dakota ranked first in the United States for sunflower production, with 351,300 ha harvested, and production valued at US$185.7 million (zharvUSDA 2010).

Sunflower is attacked by several insect species. The major insect pests of sunflower in the northern Great Plains include banded sunflower moth, *Cochylis hospes* Walsingham; sunflower beetle, *Zygogrammma exclamationis* (F.); sunflower stem weevil, *Cylindrocopturus adspersus* (LeConte); red sunflower seed weevil, *Smicronyx fulvus* LeConte; and sunflower midge, (*Contarinia schulzi* Gagné (Charlet et al. 1997). High insect pest densities have reduced yields and have led to reductions in hectarage in some production areas. Among the insect species associated with sunflower, one of the most important and damaging pest groups is head-feeding insects (Arthur and Campbell 1979a,b; Charlet et al. 1997).

In the past several years, sunflower producers, field scouts and seed companies have expressed concern about injury to sunflower resulting in deformed heads. The head damage was unlike that caused by sunflower midge or other head-feeding insects, and was attributed to feeding injury caused by a seed maggot, *Neotephritis finalis* (Loew) (Diptera: Tephritidae), and sunflower bud moth, *Suleima helianthana* (Riley) (Lepidoptera: Tortricidae) (Ganehiarachchi et al. 2009). However, the exact extent of economic loss from these insect pests is not known. Although *N. finalis* and *S. helianthana* have been reported in the literature as insect pests of sunflower, a better understanding of their economic impact and potentially useful pest management strategies is needed.

In the early 1970s, *N. finalis* was identified as potentially the most destructive pest of sunflower seed in northern Georgia and was reported to infest plants throughout the growing season (Beckham and Tippins 1972). Foote et al. (1993) also reported that *N. finalis* can be a serious pest of sunflower. *N. finalis* is distributed throughout North America, ranging from southern Alberta to Manitoba south to Virginia and Georgia and west to California and into northern Mexico (Arthur and Campbell 1979b, Foote et al. 1993). Foote (1960) described this species as one of the most commonly encountered tephritids in North America.

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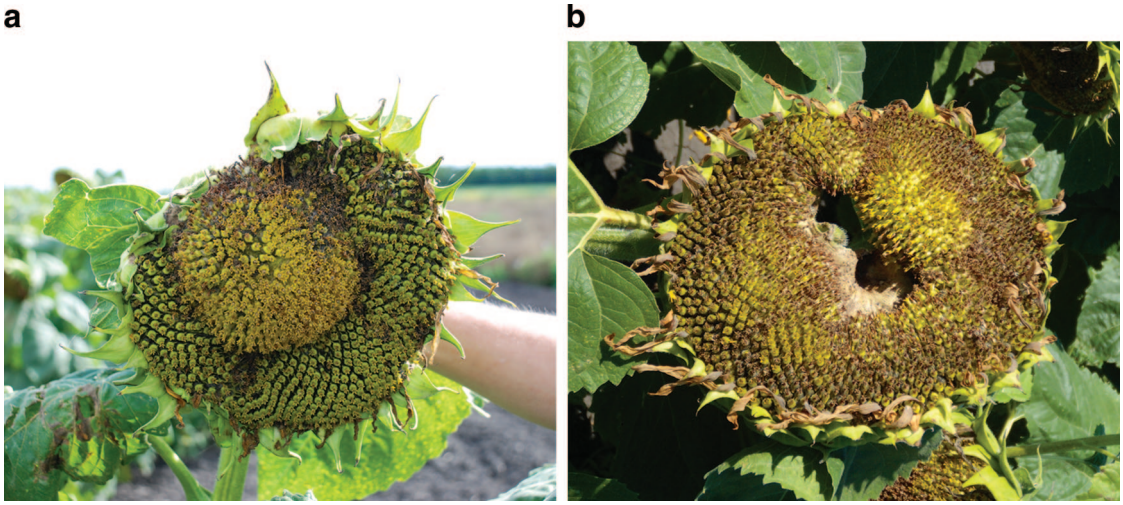

Fig. 1. (a) Damaged sunflower head caused by *N. finalis* larval feeding in early bud stage. (b) Damaged sunflower head caused by *S. helianthana* larval feeding in early bud stage.

Charlet et al. (1992) collected *N. finalis* in the heads of six native *Helianthus* species examined in North Dakota and Minnesota.

The biology and behavior of *N. finalis* in the United States and Canada were described by Kamali (1973), Goeden et al. (1987), and Arthur and Mason (1989). *N. finalis* is a multivoltine pest in southern California and adults can be found throughout the year (Goeden et al. 1987). In North Dakota and southern Canada, *N. finalis* seems to be a bivoltine insect (Kamali 1973, Arthur and Campbell 1979b; J.T.K., unpublished data). Adults typically emerge during the first week of July and lay eggs on the corollas of incompletely opened sunflower inflorescences (Arthur and Campbell 1979b). The larval stage has three instars and lasts ≈12 d (Goeden et al. 1987). The first generation pupates in the head and the small, brown pupae can be observed in the faces of sunflower heads (Goeden et al. 1987). Damage is caused by larvae tunneling into young florets (seed sterility), and consuming up to 12 developing achenes (Arthur and Campbell 1979b, Arthur and Mason 1989). The damage symptom manifests as a line or crease on the face of the sunflower head (Fig. 1a). The magnitude of damage to sunflower seeds by *N. finalis* depends largely on larval stage and timing of seed development (Knodel and Charlet 2007).

S. helianthana is widely distributed throughout sunflower growing regions of the Great Plains (Charlet et al. 1997). Hosts attacked by *S. helianthana* include wild and cultivated *Helianthus* (Rogers 1988, Charlet et al. 1992), ragweeds (*Ambrosia* spp.) and Canada thistle [*Cirsium arvense* (L.) Scop.] (Charlet et al. 1997). There are two generations per year in North Dakota (Knodel and Charlet 2007). Adults emerge from overwintering pupae from the last week of May to mid-June. A few days after adult emergence, eggs are deposited in leaf axils or on the terminals of immature sunflower heads (Charlet et al. 1997). Newly emerged larvae begin tunneling through the epidermis, usually at the leaf axil or the back of the receptacle, and feed in the fleshy plant tissues of stalks or heads (Rogers 1979). Mature larvae pupate within the host plant. Pupae move to the opening of the entrance holes formed in the stem or head tissue so that adults can emerge easily (Rogers 1979). Second generation adults appear in July and August (Charlet et al. 1997, Knodel et al. 2010b).

Major economic losses are caused from *S. helianthana* larvae burrowing into unopened buds and preventing proper head development (Fig. 1b) (Knodel and Charlet 2007).

First generation larvae occur most frequently in the growing terminal of the plant, whereas the second generation larvae typically attack the head and chew holes that occasionally cause yield loss (Rogers 1979). When plants are attacked in the early reproductive stages, flower buds are the preferred oviposition site and the entire head can be severely deformed and lost (Rogers 1979, Knodel et al. 2010b) (Fig. 1b).

Knowledge of feasible integrated pest management (IPM) strategies for control of *N. finalis* and *S. helianthana* is lacking. Cultural control strategies, such as planting dates, can modify the cropping environment and reduce pest densities while mitigating negative impacts on natural enemies (Letourneau and Altieri 1999). Planting date has been shown to effectively reduce damage, and yield loss and/or oil reduction caused by several sunflower insect pests, including sunflower stem weevil, banded sunflower moth, red sunflower seed weevil, and sunflower beetle (Oseto et al. 1982, 1987, 1989; Rogers et al. 1983, Charlet and Busacca 1986, Charlet and Knodel 2003).

Our goal was to determine whether late planting date would reduce percentage of damaged seed caused by *N. finalis* and *S. helianthana* compared with early planting date, and minimize yield loss to cultivated sunflower in various production regions throughout North Dakota. We evaluated the impact of

Table 1. Planting dates, rating dates, rating date crop stages, and harvest dates for all locations, 2009–2010

Yr	Location	Early planting date	Late planting date	Days between planting dates	Rating date	Rating crop stage (early, late)	Harvest date
2009	Carrington	29 May	17 June	19	3 Sept.	R7, R6	
	Langdon	21 May	4 June	14	16 Sept.	R8, R7	12 Oct.
	Mapleton	2 June	15 June	18	31 Aug.	R7, R6	2 Dec.
	Minot	28 May	16 June	19	2 Sept.	R7, R6	4 Nov.
	Prosper	30 May	15 June	16	1 Sept.	R7, R6	1 Dec.
2010	Carrington	26 May	8 June	13			
	Langdon	18 May	7 June	20	31 Aug.	R7, R6	1 Oct.
	Mapleton	20 May	4 June	15	27 Aug.	R7, R6	20 Oct.
	Minot	18 May	2 June	15	25 Aug.	R7, R6	20 Oct.
	Prosper	21 May	4 June	14	27 Aug.	R7, R6	11 Oct.

planting date by monitoring the population density of adult *N. finalis,* and by assessing the number of damaged heads for *N. finalis* and *S. helianthana,* and seed yield at different research locations.

Materials and Methods

Two different planting dates (early and late) were evaluated for mitigation of *N. finalis* and *S. helianthana* damage. In 2009 and 2010, trials were conducted at the Carrington Research and Extension Center, Carrington, in central North Dakota; at the Langdon Research and Extension Center, Langdon, in northeastern North Dakota; at a cooperator site near Mapleton, in southeastern North Dakota; at the North Central Research and Extension Center, Minot, in north central North Dakota; and at the North Dakota State University Agronomy Farm near Prosper, in southeastern North Dakota. The oilseed sunflower hybrid NK 2930 NS-DM (Syngenta Crop Protection, Greensboro, NC) was used at all locations. All trials were arranged in a randomized complete block design with six replications. Plots at all locations were 6.1 m in width by 9.1 m in length and consisted of eight rows with 0.75-m row spacing. Alley width between plots and replications was 3.0 m. Seeding rate was ≈49,500 live seeds per ha. Seeding rate reflects a common commercial seeding rate at these locations. Planting dates at each location in 2009 and 2010 are given in Table 1. Early and late planting dates were separated by an average of 16.3 d, with a range of 13–20 d (Table 1).

Seasonal occurrence of adult *N. finalis* was monitored biweekly in another sunflower block adjacent to the planting date study at Mapleton and Prosper in 2009 and 2010, and weekly at Carrington in 2009. The monitoring block was 50 m in width by 50 m in length and planted using the early planting date at each location. The same oilseed sunflower hybrid NK 2930 NS-DM (Syngenta Crop Protection) from the planting date study was used. Eighteen yellow sticky traps (7.6 by 12.7 cm) were placed on galvanized poles (two traps per pole) and arranged in an equilateral 3 by 3 grid within each monitoring block. Traps were positioned just above the plant canopy and adjusted as the crop grew throughout the growing season. Traps were monitored from the late vegetative growth stage through the R7 (back of head starting to turn yellow) growth stage. Growth stages follow Schneiter and Miller (1981). Traps were brought to the laboratory for *N. finalis* identification. Traps were observed under a table-mounted magnifier and the number of adult *N. finalis* was recorded. Date and growth stage also were recorded for each trap.

In 2010, visual observations of adult *N. finalis* also were recorded by counting the numbers of resting adult flies on 20 heads per plot in the late morning. In total, 120 heads were examined biweekly in the plots of both the early and late planting dates from early July through late September.

When the early planting date reached the R7 growth stage, 20 heads from the center two rows of each plot for a total of 100 heads from both planting dates were randomly selected and rated for *N. finalis* damage using a 0–8 scale, with 0 having no damage and 8 having the most severe damage. Because *N. finalis* tunnels through the developing sunflower head, the damage symptom manifests as a line or crease in the face of the sunflower head (Fig. 1a). The damage rating scale for *N. finalis* used a circle hoop (25.4 cm in diameter) divided into eight pie-sections with string and was placed over the face of the sunflower head for conducting ratings. The number of pie-sections that the feeding injury crease intersected was the final damage rating score. For example, if a *N. finalis* larva tunneled through half of the head creating a crease, it would receive a rating of 4. In addition, the percentage of damaged heads caused by *N. finalis* and *S. helianthana* was recorded by observing 100 plants at random within each plot. The four middle rows of each plot were harvested at maturity using a small-plot combine. Yields were computed and adjusted to 10% grain moisture.

Rating dates, rating date growth stages and harvest dates are given in Table 1. All data were subjected to analysis of variance (ANOVA) by using PROC GLM (SAS Institute 2008). Treatment means were separated using Fisher's protected least significant difference (LSD) test at $P \leq 0.05$. All data were tested for normality using the Kolmogorov–Smirnov test in PROC UNIVARIATE, and for homogeneity of variance using Levene's test (Levene 1960). Percentage data that did not meet the assumption of normality or homogeneity of variance

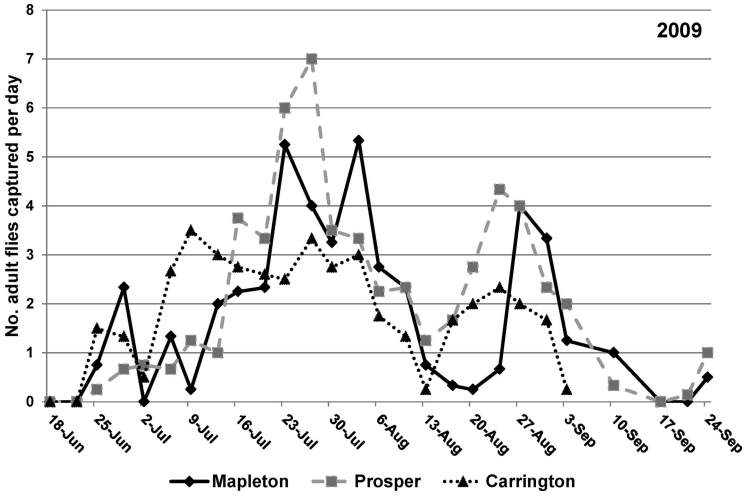

Fig. 2. Flight period of *N. finalis* based on the number of adult flies captured per day at Prosper, Mapleton, and Carrington, 2009.

were transformed using the arcsine square-root transformation before analysis. *N. finalis* and *S. helianthana* voucher specimens from the Mapleton location were deposited in the North Dakota Insect Reference Collection, Entomology Department, North Dakota State University, Fargo, ND.

Results

Monitoring with yellow sticky traps in 2009 and 2010 from multiple locations in North Dakota indicated that *N. finalis* had two complete generations per year with a partial third generation possible during warmer seasons (Figs. 2–5). Adults of the first generation began to emerge during early to mid-July when plants were in the late vegetative stage (V10–V18) to early reproductive R1 (terminal bud stage), and the second generation emerged in early to mid-August when plants were in the late reproductive crop stages R6 (flowering complete and ray petals wilting) to R7 (Figs. 2–5). At Mapleton in 2009, the first generation of adults peaked on 23 July, and second generation adults peaked on 31 August (Fig. 2). At Prosper in 2009, the first generation of adults peaked on 27 July, and second generation adults peaked on 24 August (Fig. 2). At Carrington in 2009, the population density was low, and the first generation of adults had an extended peak from 9 to 27 July (Fig. 2). The second generation of adults at Carrington peaked from 20 August to 27 August (Fig. 2). At Mapleton in 2010, first generation adults peaked from 12 to 22 July; second generation adults peaked on 10 August; and then an unusual third

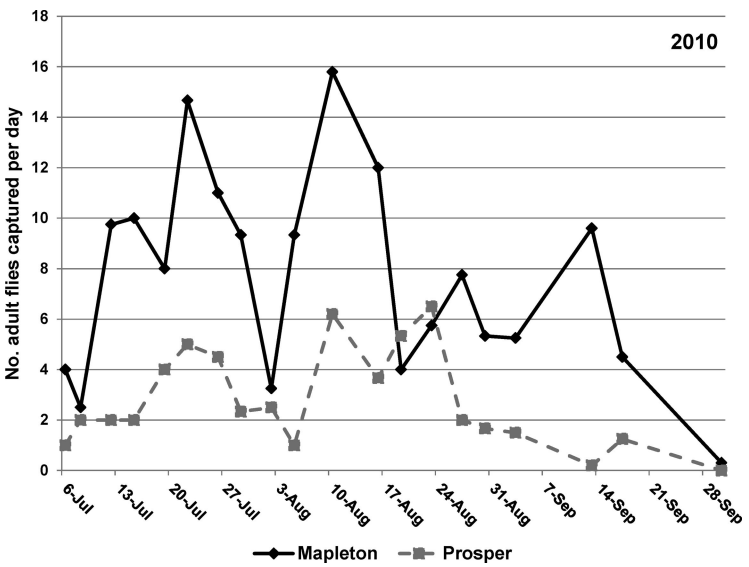

Fig. 3. Flight period of *N. finalis* based on the number of adult flies captured per day at Prosper and Mapleton, 2010.

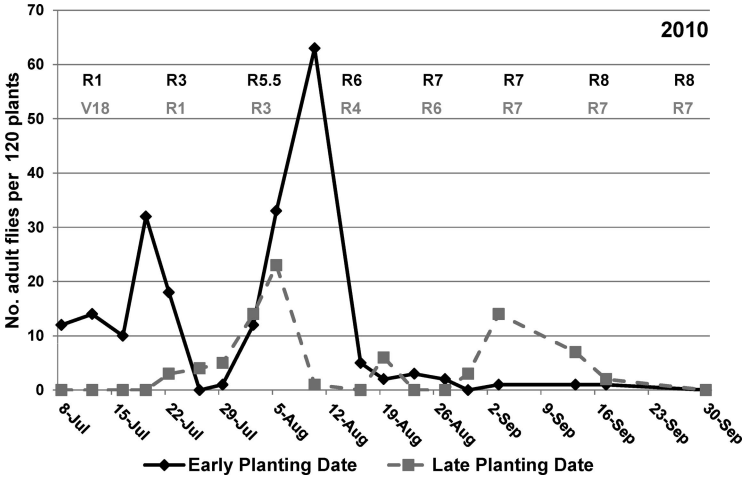

Fig. 4. Visual observations of number of adult *N. finalis* per 120 heads at Mapleton, 2010. Crop phenology for early and late planting dates is indicated at the top of graph in black and gray, respectively.

peak of adults on 13 September, indicating a possible third generation (Fig. 3). At Prosper in 2010, the *N. finalis* population was lower and only two peaks were observed. First generation adults peaked on 22 July and second generation adults from 10 to 23 August (Fig. 3). Trap catches of *N. finalis* adults at Mapleton were twice as high in 2010 as 2009, whereas Prosper had comparable trap densities of adults in both 2009 and 2010.

In total, 292 adult *N. finalis* was observed on sunflower heads at Mapleton and 155 adults at Prosper in 2010. The majority of adult *N. finalis*, 71.9 and 84.5%, were found in the early planted sunflower compared with only 28.1 and 15.5% in late planted sunflowers at Mapleton and Prosper, respectively. First and second generation adults had a higher incidence in early planted sunflower (Figs. 4 and 5), whereas adults of a possible third generation (only observed at Mapleton 2010) had a higher incidence in late-planted sunflower (Fig. 4). Adults of the second generation of *N. finalis* seemed to prefer the early planting even though younger plants were available in the later planting (Figs. 4 and 5).

At Carrington in 2009, the mean *N. finalis* damage rating in the late planting was lower than the damage in the early planting, but means were not significantly different ($F = 4.13$; df = 1, 5; $P = 0.0979$) (Table 2). Late planting had a significantly lower percentage of damaged heads for *N. finalis* ($F = 11.10$; df = 1, 5; $P = 0.0207$) and *S. helianthana* ($F = 9.76$; df = 1, 5; $P = 0.0261$) than the early planting (Table 2). Yield is not reported for Carrington in 2009 due to an error in harvesting. At Langdon in 2009, the mean *N. finalis* damage rating ($F = 2.24$; df = 1, 5; $P = 0.1949$),

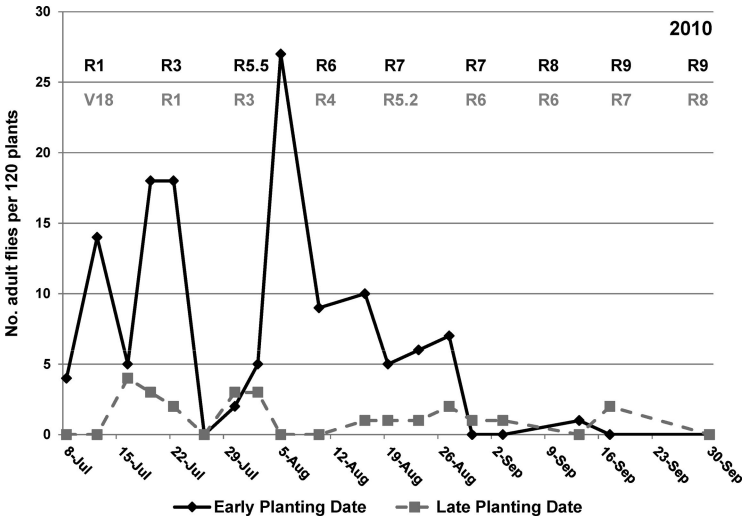

Fig. 5. Visual observations of number of adult *N. finalis* per 120 heads at Prosper, 2010. Crop phenology for early and late planting dates is indicated at the top of graph in black and gray, respectively.

Table 2. Mean *N. finalis* damage ratings, percentage of damaged heads by *N. finalis* and *S. helianthana*, and grain yield for two different planting dates at five locations in North Dakota, 2009

Location	Planting date	*N. finalis* damage rating, $\bar{x} \pm$ SE	% *N. finalis* damaged heads[a], $\bar{x} \pm$ SE	% sunflower bud moth damaged heads, $\bar{x} \pm$ SE	Yield (kg/ha), $\bar{x} \pm$ SE
Carrington	Early	0.3 ± 0.1	7.2 ± 2.2*	3.2 ± 1.0*	
	Late	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
Langdon	Early	0.2 ± 0.1	4.2 ± 3.0	3.3 ± 2.1	2,722.8 ± 119.9**
	Late	0.0 ± 0.0	0.1 ± 0.1	0.3 ± 0.2	2,176.8 ± 49.5
Mapleton	Early	0.5 ± 0.1**	11.7 ± 2.8**	0.8 ± 0.4	2,927.2 ± 217.5
	Late	0.3 ± 0.1	4.7 ± 1.5	1.0 ± 0.4	2,660.7 ± 152.8
Minot	Early	0.3 ± 0.1*	5.2 ± 1.5*	1.7 ± 0.8	
	Late	0.0 ± 0.0	0.3 ± 0.2	0.1 ± 0.1	
Prosper	Early	0.3 ± 0.1	14.5 ± 2.4	1.7 ± 0.6	3,387.8 ± 155.9*
	Late	0.3 ± 0.1	11.3 ± 1.6	4.8 ± 1.7	2,831.6 ± 164.8

*, significant at $P < 0.05$; **, significant at $P < 0.01$.

[a] Percentages of damaged heads by *N. finalis* for Mapleton were transformed using arcsine square root transformation before analysis. Actual means are presented in the table.

percentage of damaged heads for *N. finalis* ($F = 1.98$; df = 1, 5; $P = 0.2181$), or percentage of damaged heads for *S. helianthana* ($F = 2.21$; df = 1, 5; $P = 0.1970$) in the late planting were lower than the early planting, but means were not significantly different (Table 2). For yield, the early planting had significantly higher yield than the late planting ($F = 27.11$; df = 1, 5; $P = 0.0034$) (Table 2). At Mapleton in 2009, the late planting had a significantly lower *N. finalis* damage rating ($F = 17.14$; df = 1, 5; $P = 0.0090$) and significantly lower percentage of damaged heads for *N. finalis* ($F = 35.35$; df = 1, 5; $P = 0.0019$) than the early planting (Table 2). Planting date did not have a significant effect on percentage of damaged heads for *S. helianthana* ($F = 0.29$; df = 1, 5; $P = 0.6109$) or yield ($F = 0.88$; df = 1, 5; $P = 0.3917$). At Minot in 2009, the late planting had a significantly lower mean *N. finalis* damage rating ($F = 11.87$; df = 1, 5; $P = 0.0183$) and significantly lower percentage of damaged heads for *N. finalis* ($F = 9.89$; df = 1, 5; $P = 0.0255$) than the early planting (Table 2). Although late planting date had a lower percentage of damaged heads for *S. helianthana*, results were not significant ($F = 3.14$; df = 1, 5; $P = 0.1366$) (Table 2). Yield at Minot was not analyzed due to confounding effects of heavy bird damage in research plots. At Prosper in 2009, mean *N. finalis* damage rating ($F = 0.00$; df = 1, 5; $P = 0.9536$), the percentage of damaged heads for *N. finalis* ($F = 2.93$; df = 1, 5; $P = 0.1479$) and the percentage of damaged heads for *S. helianthana* ($F = 4.13$; df = 1, 5; $P = 0.0978$) were lower in the late planting date, but means were not significantly different (Table 2). The early planting date had significantly higher yield ($F = 10.22$; df = 1, 5; $P = 0.0241$) than the late planting date.

At Carrington in 2010, it was impossible to collect *N. finalis*, *S. helianthana* and yield data due to severe head damage by sunflower midge. At Langdon in 2010, the late planting date had a significantly lower *N. finalis* damage rating ($F = 6.53$; df = 1, 5; $P = 0.0500$), significantly lower percentage of damaged heads for *N. finalis* ($F = 24.00$; df = 1, 5; $P = 0.0045$) and significantly lower percentage of damaged heads for *S. helianthana* ($F = 7.35$; df = 1, 5; $P = 0.0422$) than the early planting date (Table 3). The late planting date had significantly higher yield ($F = 10.73$; df = 1, 5; $P = 0.0221$) than the early planting date (Table 3). At Mapleton in 2010, the late planting date had a significantly lower *N. finalis* damage rating ($F = 19.96$; df =

Table 3. Mean *N. finalis* damage ratings, percentage of damaged heads *N. finalis* and *S. helianthana*, and grain yield for two different planting dates at five locations in North Dakota, 2010

Location	Planting date	*N. finalis* damge rating, $\bar{x} \pm$ SE	% *N. finalis* damaged heads[a], $\bar{x} \pm$ SE	% sunflower bud moth damaged heads, $\bar{x} \pm$ SE	Yield (kg/ha), $\bar{x} \pm$ SE
Carrington	Early	—[b]			
	Late				
Langdon	Early	0.7 ± 0.1*	24.2 ± 3.5**	5.0 ± 1.3*	2,350.2 ± 119.9*
	Late	0.2 ± 0.1	4.2 ± 1.5	0.8 ± 0.8	3,051.9 ± 110.0
Mapleton	Early	1.3 ± 0.2**	29.2 ± 2.0**	4.2 ± 1.5*	2,513.6 ± 66.7*
	Late	0.3 ± 0.1	7.5 ± 1.7	0.8 ± 0.8	2,680.8 ± 61.9
Minot	Early	1.8 ± 0.2**	36.7 ± 4.9**	14.2 ± 3.3*	
	Late	0.6 ± 0.1	10.8 ± 2.0	2.5 ± 1.1	
Prosper	Early	1.3 ± 0.2*	31.7 ± 4.9**	13.3 ± 2.5**	2,181.5 ± 26.9*
	Late	0.6 ± 0.1	10.0 ± 1.3	1.7 ± 1.0	2,634.0 ± 102.0

*, $P < 0.05$; **, $P < 0.01$.

[a] Percentages of damaged heads by *N. finalis* for Prosper were transformed using arcsine square root transformation before analysis. Actual means are presented in the table.

[b] No data for Carrington.

1, 5; P = 0.0066), significantly lower percentage of damaged heads for *N. finalis* (F = 60.36; df = 1, 5; P = 0.0006) and significantly lower percentage of damaged heads for *S. helianthana* (F = 10.00; df = 1, 5; P = 0.0250) than the early planting date (Table 3). The late planting date had significantly higher yield (F = 14.23; df = 1, 5; P = 0.0130) than the early planting date (Table 3). At Minot in 2010, the late planting date had a significantly lower *N. finalis* damage rating (F = 82.29; df = 1, 5; P = 0.0003), significantly lower percentage of damaged heads for *N. finalis* (F = 42.52; df = 1, 5; P = 0.0013) and significantly lower percentage of damaged heads for *S. helianthana* (F = 9.42; df = 1, 5; P = 0.0278) than the early planting date (Table 3). Yield at Minot was not analyzed due to confounding effects of heavy bird damage in research plots. At Prosper in 2010, the late planting date had a significantly lower *N. finalis* damage rating (F = 9.43; df = 1, 5; P = 0.0277), significantly lower percentage of damaged heads for *N. finalis* (F = 40.07; df = 1, 5; P = 0.0015) and significantly lower percentage of damaged heads for *S. helianthana* (F = 30.62; df = 1, 5; P = 0.0026) than the early planting date (Table 3). The late planting date had significantly higher yield (F = 15.52; df = 1, 5; P = 0.0110) than the early planting date (Table 3).

Discussion

Use of cultural strategies can often mitigate insect pest injury on plants by manipulation of the environment, and can minimize the need for insecticides (Pedigo 2002). Results of this nine site-year study showed that *N. finalis* damage ratings and the percentage of damaged heads caused by *N. finalis* and *S. helianthana* usually decreased as planting date was delayed. For *N. finalis,* data were consistent for seven of the nine site-years, and for *S. helianthana* five of the nine site-years even though planting dates, weather and insect pest populations varied at each location. Visual observations of adult *N. finalis* also revealed that the majority of adults were observed in early planted sunflower (78.2%) compared with late planted sunflower (21.8%). This is the first report documenting the effectiveness of delayed planting to reduce damage caused by *N. finalis* and *S. helianthana.* Late planting date is a viable pest management strategy for mitigating economic damage caused by other important sunflower head-feeding insect pests. Charlet and Busacca (1986) and Oseto et al. (1989) showed that banded sunflower moth had lower numbers of larvae in late planted sunflower as demonstrated by reduced seed damaged. Charlet and Knodel (2003) found that the foliage-feeding sunflower beetle had lower adult and larval populations and lower defoliation as planting date was delayed. Oseto et al. (1982) found that a stem-infesting insect pest, sunflower stem weevil, had lower larval and adult densities in late planted sunflower in North Dakota. In Texas, Rogers and Jones (1979) also found that sunflower stem weevil was negatively impacted by delayed planting date.

Sunflower has a wide planting window and may be planted from early May to late June in the northern Great Plains; however, higher yields are usually obtained at earlier planting dates (Blamey et al. 1997, Ashley and Tanaka 2007). In a planting date study in North Dakota, late June plantings often resulted in lower yields and oil content, and often required mechanical drying of seeds, which can increase production expenses (Ashley and Tanaka 2007). The maturity of sunflower hybrids influences the yield response to planting date (Blamey et al. 1997). Wajid and Schneiter (1992) reported that late-maturing sunflower hybrids need to be planted earlier than early-maturing hybrids when the length of the growing season is a limiting factor. Although early planting date is preferred, yields can often be reduced when insect pest populations are high. In 2009, the percentage of damaged heads for both *N. finalis* and *S. helianthana* was low with an average of 8.6 and 2.1% in the early planting date, and 3.3 and 1.2% in the late planting date, respectively, across all locations. As a result, not all locations had significant differences in damage ratings and yield between early and late planting dates. Yield in 2009 was significantly higher in the early planting date compared with the late planting date at Langdon and Prosper due to other agronomic factors (weather) or bird damage, and not due directly to damage caused by *N. finalis, S. helianthana,* or both. Similar results have been observed in other sunflower insect studies where low densities of sunflower beetle at different locations and planting dates resulted in an inconsistent impact on yield (Charlet and Knodel 2003, Oseto et al. 1989). For banded sunflower moth, Oseto et al. (1989) observed that larval moth damage decreased with planting date, but corresponding yield increases were not always detected (Oseto et al. 1989).

In contrast to 2009, the percentage of damaged heads caused by *N. finalis* and *S. helianthana* was much higher in 2010, with an average of 30.5 and 8.1% in the early planting date, and 8.1 and 1.5% in the late planting date, respectively, across all locations. Consequently, late planting date had a significantly lower damage rating and percentage of damaged heads for both *N. finalis* and *S. helianthana* at Langdon, Mapleton, Minot, and Prosper. Yield also was probably impacted by *N. finalis* and *S. helianthana* in 2010, and the late planting dates had significantly higher yields than the early planting date at Langdon, Mapleton, and Prosper.

The impact from other seed-infesting insect pests, such as banded sunflower moth, was probably minimal at our study locations in 2009 and 2010. Results from the annual National Sunflower Association Survey indicated that the percentage of damaged seed for banded sunflower moth averaged just over 1% for both years in North Dakota (Knodel et al. 2010a). Sunflower insecticidal studies conducted at Prosper and Mapleton in 2009 and 2010 also showed a low percentage of damaged seed for banded sunflower moth. The untreated check plots averaged 3% in 2009 and

1.7% in 2010 at Prosper, and 3.8% in 2010 at Mapleton (J.T.K., unpublished data).

Planting date was shown to be an effective nonchemical IPM strategy that reduced head damage caused by *N. finalis* and *S. helianthana* and may reduce yield loss when insect densities are high. In addition, delayed planting is compatible with other IPM strategies, such as biological control, host plant resistance and insecticide control. Resistance among cultivated sunflower germplasm has been identified for several insect pests of cultivated sunflower and offers a potentially long-term and effective pest management strategy (Charlet et al. 2008, 2009). Charlet and Knodel (2003) found that altering planting dates was compatible with biological control of sunflower beetle and did not reduce the effectiveness of the parasitic tachinid fly *Myiopharus macellus* (Rheinhard) that attacks sunflower beetle larvae. Use of cultural strategies will not result in 100% control or eliminate the need for other potentially effective pest management strategies for *N. finalis* and *S. helianthana.* Additional research is needed to determine proper pest monitoring techniques and economic thresholds and injury levels and to identify other feasible IPM strategies for mitigating damage caused by *N. finalis* and *S. helianthana* in cultivated sunflower production.

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