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PLANT STAGE SUSCEPTIBILITY AND ECONOMIC INJURY LEVEL FOR TARNISHED PLANT BUG, *Lygus lineolaris* (*Heteroptera: Miridae*), ON CONFECTION SUNFLOWER

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SUMMARY

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), feeding on developing sunflower seed causes kernel brown spot, a serious problem in confection sunflower. The purpose of this research was to determine the economic injury level and plant stage susceptibility for confection sunflower in greenhouse and field studies using sunflower heads artificially infested with *L. lineolaris* adults. Greenhouse experiments showed each adult damaged 38 seeds per head. Field studies showed a lower average damage in heads infested with seven adults compared with heads with five adults, possibly due to interference among the adults and nymphs. The regression equation used to predict the number of kernel brown spot damaged seeds per head based on adults per head was Y=-0.86+33.54X. Thus, feeding resulted in 32.7 damaged seeds per head per adult. Approximately 5% of seeds in a head were damaged per adult. Damage to sunflower heads was approximately twice as severe when *L. lineolaris* infestation occurred at growth stages R4 and R5 compared with stages R6 and R7. Thus, protection of sunflower plants from infestation by tarnished plant bug, until they have completed blooming, may prevent economic loss. The economic injury level for tarnished plant bug was one adult per 10 to 15 plants, each head averaging 500 to 600 seeds, for a damage level of 0.5%. Thus, tarnished plant bug management should be initiated between the R4 to R5.1 stage if adult densities approach the economic injury level. Also, fields need to be monitored until bloom is completed to reduce incidence of kernel brown spot damage to confection sunflower

Key words: tarnished plant bug, *Lygus lineolaris*, economic injury level, nonoilseed or confection sunflower, *Helianthus annuus*, lygus bugs, insects, entomology

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INTRODUCTION

Beginning in 1998, confection or nonoilseed sunflower (*Helianthus annuus* L.) growers in the north central United States and the adjacent Canadian province of Manitoba noticed that an increasing number of kernels were discolored with small brown to black spots. Typically, the kernels had a single spot on the distal end, and the blemish was superficial with little tissue degradation. The brown spots were visible on raw dehulled kernels and became darker and more pronounced after roasting. At times there was a visible brownish area on the exterior of the hull of seeds in which the kernel had a spot. Some end users in the food industry rejected seed lots with brown spot, and this in turn caused the local processors and buyers to examine seed lots for the presence of brown spot and either reject or assess dockage for seed lots with excessive levels of brown spot (Charlet *et al.*, 2001).

Incidence of the condition, termed "kernel brown spot," on confection sunflower is sufficiently high that there is a need for understanding the underlying causes and means to alleviate the problem for growers and processors. The quality issue is significant because the food standard set by the industry is only 0.5% damage in the finished product and the incidence of kernel brown spot damage ranged between 1-14% in some areas in the Northern Plains of the United States in 2000 and 2001 (Sayler, 2001; Charlet, 2002).

Lygus bugs feeding on the developing sunflower seed were determined to be the cause of kernel brown spot. The most common insect species occurring in the affected sunflower fields was the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) (Hardin, 2002; Charlet, 2002). This species attacks at least 385 different plant species and occurs in 39 U.S. states and five Canadian provinces (Young, 1986). Adults overwinter in leaf litter and there are probably at least two generations per year in the North Central Plains of North America (Gerber and Wise, 1995). Knott *et al.* (2003) reported that the tarnished plant bug was present on a number of crops in the area besides sunflower including alfalfa, sugarbeet, and dry beans. The insects probably followed a seasonal pattern based on crop development moving to a crop as it reached the reproductive stage and leaving as it senesced. They indicated that alfalfa probably served as a reservoir crop with insects migrating to it from overwintering habitats, feeding, reproducing, developing, and finally new generation adults leaving when harvest occurred. *Lygus* spp. feed preferentially on either the developing reproductive organs or on the apical meristematic and leaf primordial tissues. Feeding injury causes a necrosis around the feeding site due to the injection of enzymes (Schwartz and Foottit, 1992). This tissue destruction causes the visible symptoms described as kernel brown spot and also can result in a bitter taste to the seeds (Charlet, 2002). Laboratory studies of the tarnished plant bug showed that eggs hatched in 6 to 8 days and development through the five nymphal stages took 14 to 18 days when reared at 24 to 28°C (Khattat and Stewart, 1977). Snodgrass and McWilliams (1992) in their rearing

investigations reported that *L. lineolaris* developed from mature eggs to the adult stage in about 17 days.

In North America, plant bugs have not been reported to cause economic damage to sunflower (Rogers, 1992; Charlet *et al.*, 1997). However, research in Hungary and other eastern European countries reported that *Lygus* spp., especially *L. rugulipennis* Poppius and *L. pratensis* L., attacked oilseed sunflower, reducing seed oil content and the viability of the seeds used for planting the following year (Charlet *et al.*, 1997; Bujaki *et al.*, 1998). In France, these two species of *Lygus* were responsible for wilted plants, aborted heads, and reduced seed numbers when plants were infested before the bud stage (Badenhausser *et al.*, 1988). The purpose of this research was to determine the economic injury level and susceptible plant stages for the tarnished plant bug on confection sunflower through a combination of greenhouse and field studies.

MATERIALS AND METHODS

Greenhouse Study

An investigation to determine tarnished plant bug economic injury level was initiated in the greenhouse in 2002, using potted confection (Pioneer hybrid 6946) sunflowers at growth stage R5.1 (onset of anthesis) (Schneiter and Miller, 1981). A total of eight plants were used for each infestation level (0, 1, 2, 5, *L. lineolaris* adults per plant). The adults were from a colony reared in the greenhouse on potted sunflower plants. Adults were placed inside ventilated plastic pollinating bags on the sunflower heads and the bags were secured around the plant stem. Tarnished plant bug adults were allowed to feed and develop for 14 days and then all *L. lineolaris* adults were counted and removed from the sunflower heads. Heads were rebagged to prevent reinfestation. Any *Lygus* bug nymphs present also were removed. Plants were allowed to continue development until physiological maturity and then heads were removed, dried, threshed, and all the seed collected for evaluation. The number of seed per individual heads was counted, the seed dehulled, and the kernels examined for kernel brown spot damage. The ANOVA option of the SAS-GLM procedure was used to compare the total number of seeds per head and number of kernel brown spot damaged seeds per head (SAS Institute, 1990). Significant differences among means were separated using Fisher's LSD, and a regression analysis was used to predict the number of seeds damaged based on adult infestation levels ($P<0.05$).

Field Studies

Twelve-row plots 7 m in length with rows 76 cm apart, and plants spaced 30.5 cm within rows were seeded using a confection hybrid (Seeds 2000 Bigfoot) sunflower at Fargo, North Dakota, on 24 and 31 May, and 6 June 2002, to provide for

a variety of different plant growth stages to conduct studies to determine both susceptible plant stage and economic injury level for the tarnished plant bug.

Greenhouse-reared adults were used to determine the economic injury level for *L. lineolaris* by confining them on sunflower heads when the heads reached the R5.1 growth stage. Heads were previously bagged at the R3 stage on 23 July. A total of 15 of the bagged sunflower heads were randomly selected and each head was infested with either 0, 1, 2, 5, or 7 adults per head, during the period 29 July through 1 August. After 14 days, all tarnished plant bug adults were removed from the heads and counted to ensure that all had been recovered and the heads were then rebagged to prevent reinfestation.

The most susceptible plant stage for sunflower infestation by *L. lineolaris* was determined by initially bagging randomly selected heads at the R4 growth stage on 22 July. As heads in the field plots reached growth stages R4, R5.1, R5.5, R6, and R7, greenhouse-reared tarnished plant bugs were confined (five adults per head) on 15 randomly selected heads of each stage, and 15 uninfested heads remained as controls. Infestations of tarnished plant bugs took place from 26 July to 13 August. All *L. lineolaris* were removed from heads after 3 days to ensure feeding was only occurring at the growth stage selected, and the heads were rebagged to prevent reinfestation.

After plants reached physiological maturity, the sunflower heads from both the economic injury level and the susceptible plant stage studies were removed for evaluation. The heads were dried, threshed, the seeds cleaned, and the seeds from individual heads were counted and dehulled. A total of 200 randomly sampled kernels from each head were subsequently examined for kernel brown spot feeding damage caused by *L. lineolaris*.

The ANOVA option of the SAS-GLM procedure was used to compare the total number of seeds per head and number of damaged seeds per head for each study (SAS Institute 1990). Significant differences among means were separated using Fisher's LSD and a regression analysis was used to predict the number of seeds damaged based on adult infestation levels ($P<0.05$).

RESULTS AND DISCUSSION

Greenhouse Study

Experiments conducted in the greenhouse showed that approximately nine seeds per head were damaged and exhibited kernel brown spot (Figure 1) when infested with 1 adult, and 171 seeds were damaged in heads infested with five *L. lineolaris* adults per head (Table 1). There were no significant differences in kernel brown spot among the control and those infested with one or two adults per head ($F=3.89$; df=3,25; $P=0.0208$). This was likely because of the large variation in the

damage among the infested heads. There was no difference in the number of seeds per head for any of the treatment levels (F=0.41; df=2,25; P=0.7457) (Table 1).

Table 1: Mean number of seeds per head, kernel brown spot damaged seeds, and percentage of damaged seeds resulting from confection sunflower heads infested at the R5.1 stage with different numbers of adult tarnished plant bug in the greenhouse, Fargo, North Dakota, 2002

Treatment*	No. plants	No. seeds per head Mean ± SE**	No. damaged seeds per head Mean ± SE**	% damaged seeds Mean ± SE
0 / head	6	448.8 ± 93.5a	6.0 ± 3.7a	1.2 ± 0.8
1 / head	8	511.9 ± 41.8a	9.3 ± 5.3a	1.8 ± 1.0
2 / head	8	531.0 ± 31.7a	107.3 ± 36.2ab	18.3 ± 5.8
5 / head	7	457.3 ± 83.0a	171.3 ± 71.8b	41.4 ± 12.5

* Heads infested with adult *L. lineolaris* for 14 days.
** Means followed by the same letter are not significantly different at $P < 0.05$; LSD.

The control showed almost as much damage as the average for those infested with one adult, due to adults accidentally entering two of the six bagged heads. Earlier research had determined that the only cause for the kernel brown spot damage was feeding by *Lygus* bugs (Charlet *et al.*, 2001). Because heads were infested for a total of 14 days, the injury was a combination of both adult and nymphal feeding. Eggs had been laid on many of the heads and nymphs were present when the insects were removed. The regression equation used to predict the number of seeds damaged per head based on adults per head was Y=2.39+35.55X (SE a=10.97, SE b=29.87, P=0.003). Thus, each adult results in 37.9 damaged seeds per head. The r^2 of only 0.28 showed that there are other variables unaccounted for that also influence the damage caused by tarnished plant bug in the sunflower head.

Figure 1: Kernel brown spot damage to confection sunflower kernels caused by tarnished plant bug feeding.

The seed feeding damage resulted in 1.8 and 41.4% seeds with kernel brown spot per head infested with 1 and 5 *L. lineolaris* adults, respectively. The study showed that one tarnished plant bug adult caused an average of 7% seed damage.

This level is much higher than the tolerance of 0.5% set by the industry for the finished product. Based on this greenhouse trial and the 38 predicted number of seeds damaged per adult tarnished plant bug, the economic injury level would be one adult per 15 plants averaging 500 seeds per head for a 0.5% level of damage.

Field Studies

The study to determine kernel brown spot damage to sunflower seeds from different densities of *L. lineolaris* adults in field plots showed greater injury to seeds as densities increased from one to five adults per head (F=9.27; df =4,59; P=0.0001) (Table 2). There were no significant differences in the number of seeds per head among the treatments (F=1.00; df=4,60; P=0.4155). The damage was similar between heads infested with one or two adults per head. Kernel brown spot damage was significantly higher among heads infested at five to seven adults. There was some seed injury in the control plants because tarnished plant bugs present in the field accidentally entered the bagged heads. The determination of the number of seeds per head with kernel brown spot showed lower average damage in those infested with seven adults compared with those infested with five adults, but the difference was not significant. It is possible with higher densities of tarnished plant bugs interference among the adults and nymphs on the heads may have reduced feeding. It has also been noted that cannibalism occurs among *L. lineolaris* nymphs (Khattat and Stewart, 1977; Snodgrass and McWilliams, 1992).

Table 2: Mean number of seeds, kernel brown spot damaged seeds, and percentage of damaged seeds resulting from confection sunflower heads infested at the R5.1 stage with different numbers of adult tarnished plant bug in the field, Fargo, North Dakota, 2002

Treatment*	No. plants	No. seeds / head Mean ± SE**	No. damaged seeds / head Mean ± SE**	% damaged seeds Mean ± SE
0 / head	8	627.3 ± 67.8a	7.0 ± 2.9a	0.9 ± 0.3
1 / head	14	706.6 ± 56.7a	22.2 ± 6.6a	3.3 ± 1.1
2 / head	14	572.1 ± 40.9a	53.0 ± 22.6a	8.6 ± 3.5
5 / head	14	600.9 ± 55.5a	215.7 ± 39.1b	37.8 ± 5.9
7 / head	14	632.9 ± 44.0a	204.3 ± 49.5b	29.5 ± 7.2

* Heads infested with adult *L. lineolaris* for 14 days

** Means followed by the same letter are not significantly different at $P < 0.05$; LSD.

The calculation of the number of seeds with kernel brown spot damage per head showed that approximately 22 seeds per head were injured when sunflower heads were infested with one *L. lineolaris* adult, and over 200 seeds per head when infested with five to seven *L. lineolaris* adults. The regression equation used to predict the number of seeds damaged per head based on adults per head was Y=-0.86+33.54X (SE a=5.82, SE b=24.2, P=0.0001). Thus, accumulated adult and nymphal feeding resulted in 32.7 kernel brown spot damaged seeds per head per adult. This is similar to the 38 seeds damaged per adult determined in the greenhouse trial. The r^2 of only 0.35 showed that there are other variables unaccounted

for that also influence the damage caused by tarnished plant bugs. Based on the results of this study there was an average contribution of 5% of seeds damaged per one tarnished plant bug adult infesting a sunflower head. Thus, an economic injury level based on this study would be one adult per 10 heads for plants containing approximately 600 seeds per head to ensure 0.5% or less kernel brown spot seed damage.

Table 3: Mean number of seeds and number of kernel brown spot damaged seeds resulting from confection sunflower heads infested with adult tarnished plant bug at different plant growth stages in the field, Fargo, North Dakota, 2002

Treatment*	No. plants	No. seeds / head Mean ± SE**	No. damaged seeds / adult Mean ± SE**	% of damaged seeds Mean ± SE
Control	8	543.1 ± 40.3a	0.5 ± 0.2a	0.1 ± 0.0
R4	11	690.7 ± 40.9a	13.7 ± 3.2c	2.0 ± 0.5
R5.1	13	569.6 ± 48.2a	9.1 ± 3.9bc	1.7 ± 0.8
R5.5	13	574.6 ± 45.5a	10.9 ± 4.0bc	1.8 ± 0.7
R6	13	528.5 ± 42.4a	2.3 ± 0.6ab	0.5 ± 0.2
R7	12	536.4 ± 57.8a	4.8 ± 1.2abc	0.8 ± 0.2

* Heads infested with 5 adult *L. lineolaris* for 3 days; control heads bagged from R4-R8 stage
** Means followed by the same letter are not significantly different at $P < 0.05$; LSD.

The investigation to determine plant stage susceptibility for sunflower infestation by *L. lineolaris* adults showed that adults infesting plants between growth stages R4 to R7 caused kernel brown spot seed damage (Table 3). There were no differences in the number of seeds among the treatments ($F=1.54$; df=5,64; $P=0.1914$). Levels of injury were less than in the economic injury study for the same density (five adults per head) because heads were only infested for 3 days. The shorter infestation period was utilized to avoid an overlap of growth stages exposed to tarnished plant bug feeding. Damage to sunflower heads was approximately twice as severe when infestation occurred during growth stages R4 and R5 compared with stages R6 and R7. However, statistically significant differences were only detected between stages R4 and R6, likely because of variation in damage among individual infested heads ($F=2.95$; df=5,64; $P=0.0185$). Because seeds are not present at the R4 plant growth stage, the kernel brown spot damage occurring in plants infested at the R4 stage was probably a result of feeding by tarnished plant bug progeny from eggs deposited during the three days of infestation. Some damage from nymphal feeding likely occurred on heads infested at the other growth stages as well. Although the adults used to infest the sunflower heads had been removed, due to time constraints, heads were not continually monitored for *L. lineolaris* nymphs during the remainder of the growing season. At growth stage R6, the percentage of kernel brown spot damage per *L. lineolaris* adult was only 0.5%, the level of the industry standard for damage and at R7 the damage was only slightly higher at 0.8%. Thus, protection of sunflower plants from infestation by tarnished plant bug, until they have completed blooming, may prevent kernel brown spot damage

levels from resulting in economic loss to the producer due to rejection or dockage for levels above 0.5%.

The results of these investigations were based on confining tarnished plant bug to individual heads to ensure exact numbers of adults infesting the heads. Because adults are highly mobile, infest and feed on a number of crops, and readily move from plant to plant, additional work using large cages or tests of plants naturally infested could provide additional information on tarnished plant bug infestation dynamics and also would be useful in validating the results to cultivated field conditions.

CONCLUSIONS

Based on greenhouse and field studies, *L. lineolaris* adults are able to cause feeding injury resulting in kernel brown spot damage to sunflower at low adult densities. Confection sunflower is vulnerable to attack by tarnished plant bug from the late bud stage (R4) through flowering, although damage is reduced in later stages (R6 to R7). Regression analysis showed that infestation by each adult *L. lineolaris* can result in kernel brown spot damage of 33 to 38 seeds per head depending on the number of seeds contained in the head. Thus, the economic injury level for tarnished plant bug would be one adult per 10 to 15 plants with heads averaging 500 to 600 seeds for a kernel brown spot damage level of 0.5%. Sunflower heads containing higher numbers of seeds could therefore sustain slightly higher numbers of *L. lineolaris* adults before economic loss occurred. The blending of confection seed lots can sometimes maintain the finished crop at or below the 0.5% level of damage. Thus, in some instances levels of 1 to 2% kernel brown spot damage may be allowed by the processors without dockage depending on overall crop conditions for the season. This also would have an impact on the economic injury level, and higher densities of tarnished plant bug adults could be tolerated before management was required. The results of these studies revealed that management of tarnished plant bug in confection sunflower should be initiated between the R4 to R5.1 stage if densities of tarnished plant bug adults approach the economic injury level, and fields need to be monitored until bloom is completed to reduce the incidence of kernel brown spot damage in confection sunflower.

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This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement of recommendation by USDA for its use.

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FASE SENSIBLE DEL DESARROLLO Y EL NIVEL DEL IMPACTO ECONÓMICO DEL INSECTO *LYGUS LINEOLARIS* (*Heteroptera: miridae*) EN EL GIRASOL DE CONFITERÍA

RESUMEN

Lygus lineolaris (Palisot de Beauvois) que se alimenta con la semilla de girasol en desarrollo, causa *kernel brown spot*, lo que representa un problema serio, cuando se trata del girasol de confitería. El objetivo de esta investigación fue determinar el nivel del impacto económico y las fases de desarrollo, en las cuales el girasol es sensible a plaga, dentro de las investigaciones en el invernadero y en el campo, utilizando las cabezas de girasol, infectadas artificialmente con individuos adultos de *L. lineolaris*. Las investigaciones en el invernadero mostraron que un individuo adulto provoca daño en 38 semillas por cabeza.

Las investigaciones en el campo mostraron que el impacto promedio era más bajo cuando en la cabeza se encontraba siete individuos adultos que cuando en la cabeza se encontraba cinco individuos, lo más probable porque los individuos adultos y crisálidas se molestaban mutuamente. La ecuación de regresión utilizada para la previsión del número de semillas dañadas por cabeza a base del número de individuos adultos por cabeza, era Y=-0.86+33.54X. Eso significa que la nutrición de las plagas ha causado deterioros en 32,7 semillas por cabeza por individuo. Alrededor de 5% de semillas era deteriorado por individuo. Hablando de groso modo, los daños en girasol eran doble de grande cuando *L. lineolaris* aparecía en las fases de desarrollo R4 y R5, que cuando aparecía en las fases R6 y R7. Eso significa que la protección de girasol de *L. lineolaris* hasta el final de floración, puede impedir pérdidas económicas. Para lograr el nivel del impacto económico de 0,5%, era preciso un individuo en 10 a 15 plantas, con cabezas de 500 a 600 semillas en promedio. Hay que empezar con la protección contra *L. lineolaris* entre las fases R4 y R5.1, si la densidad de insectos se acerca al nivel del impacto económico. También es preciso seguir la situación en el campo hasta el final de floración, para disminuir la aparición de *kernel brown spot* en el girasol consumible.

PHASE SENSIBLE DU DÉVELOPPEMENT ET NIVEAU DES PERTES ÉCONOMIQUES PROVOQUÉES PAR L'INSECTE *Lygus lineolaris (Heteroptera: miridae)* DANS LE TOURNESOL INDUSTRIEL

RÉSUMÉ

Le Palisot de Beauvois (*Lygus lineolaris*), qui se nourrit de la graine de tournesol en développement, cause l'apparition de taches brunes sur le noyau, problème important dans la production du tournesol industriel. Le but de cette recherche était d'établir, au moyen de têtes de tournesol infectées artificiellement par des individus adultes de l'insecte *L. lineolaris,* le niveau de perte économique et la phase de développement au cours de laquelle le tournesol est sensible en serre ou dans les champs. Les recherches en serre ont montré qu'un individu adulte cause des dégâts sur 38 graines par tête. Les recherches dans les champs ont montré que les dégâts moyens étaient inférieurs quand il y avait sept individus adultes sur la tête que quand il y en avait cinq, probablement parce que les individus adultes et les nymphes se nuisaient les uns les autres. L'équation de régression utilisée pour prédire le nombre de taches brunes sur le noyau par tête selon le nombre d'individus adultes par tête était Y=-0.86+33.54X. Cela signifie que l'alimentation des insectes causaient des dégâts sur 32,7 graines par tête par individu adulte. Environ 5% des graines d'une tête étaient endommagées par adulte. Les dégâts aux têtes de tournesol étaient approximativement deux fois plus graves quand l'infection par *L. lineolaris* apparaissait aux stages de développement R4 et R5 que quand elle avait lieu aux stages R6 et R7. Ainsi, la protection des plants de tournesol avant leur floraison complète pourrait-elle empêcher des pertes économiques. Pour arriver à un niveau de perte économique de 0,5%, il a fallu un individu pour 10 à 15 plantes à tête de 500 à 600 graines en moyenne. Il faut commencer à protéger la plante du *L. lineolaris* entre les phases R4 et R5.1 si la densité des insectes s'approche du niveau de dommage économique. Il est aussi nécessaire de contrôler la situation dans les champs jusqu'à la fin de la floraison pour diminuer l'apparition de la moucheture brune du noyau dans le tournesol industriel.