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Wheat head armyworm monitoring: a survey and lure dose response in Montana, USA

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ABSTRACT

Dargida diffusa (Walker), found throughout the United States, causes sporadic damage to cereal crops. Its larvae feed during summer (May-July) on the heads of the growing crop during night. In the present study, (Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald), as pheromone, was used to attract male adults in two counties of Montana (2015–2018). Lure dose response was assessed by using 1 mg, 3 mg, and 10 mg doses. Sweep netting was also used to the survey the population of *D. diffusa*. The dose response study revealed that although higher dose (10 mg) attracted a numerically greater number of adults no significant difference was found among the treatments. Results indicated that the pheromone attracted the males of *D. diffusa* at all the study sites indicating the presence of this pest in Montana and efficacy of lures at lower dose (1 mg) compared to the control and higher doses.

Key words: *Dargida diffusa*, pheromone, traps, Golden Triangle Area, pest-monitoring

Dargida diffusa (Walker) and *Dargida terrapictalis* (Buckett) (Lepidoptera: Noctuidae) are the two members of the wheat head armyworm complex. *Dargida terrapictalis* is native to the temperate western North America (Buckett 1969) while *Dargida diffusa* is of unknown origin (Roberts *et al.* 2017). Both the species, earlier kept under Faronta and later moved to *Dargida* in 2005 (Rodriguez and Angulo 2005), are found throughout the United States (Roberts 2008; Peairs et al. 2010) and are closely related to each other (Roberts et al. 2017). While *D. diffusa,* considered to be a minor pest with sporadic outbreak causing occasional crop injury (Peairs 2008; Michaud et al. 2007), incur yield loss of 35 per cent in spring wheat in Washington State (Roberts 2009a, 2009b), *D. terrapictalis* does not hold a pest status (Landolt et al. 2011). The adult moths of both the species have apparent differences. However, differentiating them on larval basis being not possible, make the accurate damage assessment by any of the species ambiguous (Peairs 2008).

D. diffusa adult moths are yellowish brown with a prominent chocolate-colored stripe along the length of it each forewing. The color of larvae depends on the maturity of the consumed grain and varies from greenish to cream with a line down each side of the body (Michaud et al. 2007). Adults emerging during the spring season (March-May) lay eggs on a wide variety of members of Poaceae. Larvae go through five instars from May to July. Maximum larval populations are observed around mid-June (Michaud et al. 2007). They pass winter in the soil in the pupal stage (Peairs 2006). The life cycle passes in to two or three generations per year (Peairs 2006; Roberts et al. 2017). The first generation of larvae feeds on maturing heads causing direct damage to kernels, whereas second generation moths emerge and lay eggs in summer (June–August). Adults flying in autumn (October) are considered either a third generation or a late-developing second generation (Michaud et al. 2007).

The damage caused by larvae in the late spring coincides with wheat flag leaf development (Michaud et al. 2007). They feed on wheat heads primarily during night when ambient temperature is cooler and migrate towards the base of the plant with the increase of temperature during the day (Michaud et al. 2007; Royer 2007). Since the damage by these resembles much with that of the stored grain pests, the assessment of extent of damage caused by them becomes tough (Michaud et al. 2007). Cereal crops (wheat and barley) are although its major host, they are reported to feed on timothy grass (*Phleum pretense*; Poaceae) also. The damage caused by *D. diffusa* and *D. terrapictalis* is commonly known as 'insect-damaged kernels (IDK)' and is reported from Washington, Idaho and Oregon in USA (Rondon et al. 2011; Roberts et al. 2017).

For management purposes currently, there are no thresholds levels available (Peairs et al. 2010). Although, no established management strategies for this pest occur as of now, some general control tactics including chemical and biological control methods are in practice. Some natural predators such as ground beetles (Coleoptera: Carabidae), true bugs (Hemiptera), spiders (Arachnida), birds, and

rodents predating generally on all armyworms including the true armyworm, *Pseudaletia unipuncta* (Haworth). The fall armyworm, *Spodoptera frugiperda* J.E. Smith (Capinera 2005 and 2006) are also believed to prey on *D. diffusa* and *D. terrapictalis* (Roberts et al. 2017). Parasitoids such as *Meteorus autographae* Muesebeck, and *Cotesia marginiventris* (Cresson) (Hymenoptera: Braconidae), reported on armyworms (Capinera 2005 and 2006), also parasitize wheat head armyworm (Roberts et al. 2017). Moreover, in 2007, an unidentified parasitic wasp from pupae was collected in Washington, USA (Roberts et al. 2017). There are no specific insecticides to manage wheat head armyworm. However, insecticides effective against other armyworms are supposed to control this pest as well. Synthetic pyrethroids are reported to control its population under field conditions in Pacific Northwest (parts of North America and Canada) especially when sprayed during the period of maximum larval activity in the early morning and late evening (Michaud et al. 2007; Roberts et al. 2017). Reddy and Antwi (2016) tested commercially available botanicals and microbial insecticides such as Entrust®WP (spinosad 80%), Mycotrol®ESO (*Beauveria bassiana* GHA), Aza-Direct® (azadirachtin), Met52®EC (*Metarhizium brunneum* F52), Xpectro®OD (*Beauveria bassiana* GHA + pyrethrins), and Xpulse®OD (*Beauveria bassiana* GHA + azadirachtin)] at different rates in the laboratory and found spinosad the best resulting in about 80 percent larval mortality. Combination of *B. bassiana* GHA with pyrethrins and azadirachtin also showed promising results (Reddy and Antwi 2016).

Due to the scarcity of information about *D. diffusa* and *D. terrapictalis* and management strategies to control them, a thorough monitoring of this pest is very necessary (Michaud et al. 2007). For monitoring purposes, Underhill et al. (1977) reported that *D. diffusa* attracted to the lures which were baited with a combination of the sex attractant compounds Z11-16Ac and Z11-16Ald. Further, in 2011, a study showed that the combination of these two compounds also attracted *D. terrapictalis* in wheat fields of Oregon and Washington states of USA (Landolt et al. 2011). Later on, pheromone traps installed in Washington and Oregon states captured both *D. diffusa* and *D. terrapictalis* and the difference in the population of trapped insects depended on seasonal variation in population of both insects (Roberts et al. 2017). The pheromone traps are recommended to be put out when winter wheat enters the boot stage (April–May) and the monitoring be done weekly (Roberts et al. 2017).

Keeping the above facts in view, the effieacy of pheromone and its doses on population of *D. diffusa* in Montana (a part of Pacific Northwest region) was assessed.

MATERIALS AND METHODS

The survey was conducted in the Golden Triangle Area of Montana, USA, a grain producing area with rolling hills and gentle slopes, during 2015 to 2018. The survey and lure dose response was tested at four locations in Pondera county (Ledger (N 48R"35.823' W111R"12.481'), Conrad (N 48R"14.980' W111R"59.926'), Western Triangle Agricultural Research Center (WTARC) (N 48R"18.625' W111R"55.523'), Lothair (N 48R"18.457′ W111R"55.523') and in three locations in Choteau (Highwood (N 47R"35.8' W110R"47.28'), Carter (N 47R" 80.020′ W111R"20.748′) and Floweree (N 47R"43.47' W111R"01.39') during 2016, 2017, 2018 in the former and during 2015 in the later, respectively. In 2016, 2017 and 2018, the population was monitored at Carter location only.

The survey and the monitoring of the insect pest was performed by using pheromone trap, specifically designed for *D. diffusa males* (Fig. 1A and 1B) and the sweep net sampling done weekly in early morning hours. About 50 sweeps in each replication was done. Four treatments of pheromone traps, comprising of control (no lure), lure with 1 mg, 3 mg, and 10 mg of pheromone (rubber septa impregnated with (Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald) in 9:1 ratio with Hercon Vaportape) at a distance of 5-7 meters between them at each site, were established. PHEROCON® unittraps (Trécé, Oklahoma, USA) with rubber septa, each impregnated with the pheromone compounds [(Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald)], was established at selected sites of Pondera and Choteau counties. The rubber septa were loaded with 0, 1, 3 and 10 mg of pheromone compounds. The trap catches were recorded weekly and the adults were removed and counted. The data were analyzed using One-way ANOVA followed by Tukey's test (R Core Team).

Fig. 1: A: Wheat head armyworm larvae and damaged wheat seeds. B: PHEROCON Unitrap in winter wheat fields at Western Triangle Agricultural Research Center.

RESULTS AND DISCUSSION

The results of both the sites is Pondera and Choteau counties showed that majority of wheat head armyworms adults and larvae were captured during mid-June to early July. The highest adults were captured between last week of June and first week of July, irrespective of locations. (Figure 2A, 2B). Based on one-way ANOVA, the study showed significant effect of treatments on capture of total cumulative *D. diffusa* adults and total average count at both Pondera (total cumulative count; df = 3, 12; F = 7.16; P Â 0.001 and average count; df = 3, 12; F = 8.00; P Â 0.001) and Choteau (total cumulative count; df = 3, 4; F = 19.67; P Â 0.001 and average count; df = 3, 4; F = 6.00; P = 0.4) locations. Regardless of study locations, significantly higher number of wheat head armyworms were captured on pheromone lure treatments against almost zero counts of wheat head armyworms under control (Figure 3A, 3B; Figure 4A, 4B). (Landolt et al. 2011) reported that combination of '(Z)-11-hexadecenyl acetate (Z11-16Ac) and (Z)-11-hexadecenal (Z11-16Ald)' attracted both *D. diffusa* and *D. terrapictalis*. In present study, this pheromone also attracted some population of *D. terrapictalis* but the majority were of *D. diffusa*. This indicated a higher

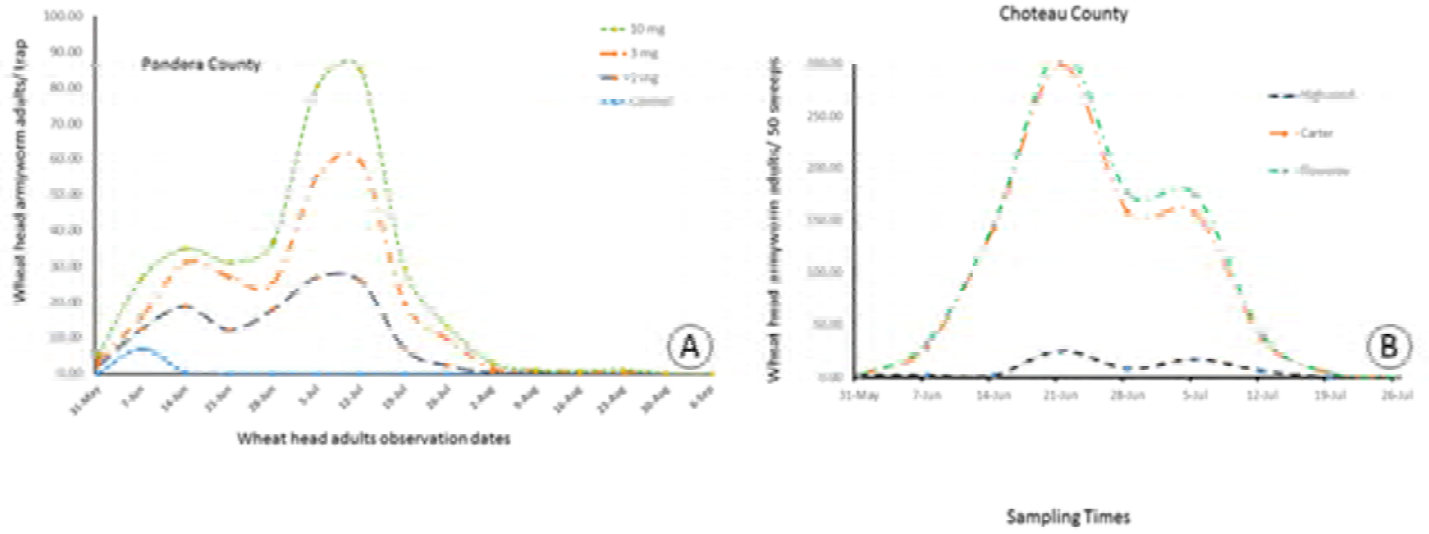

Fig. 2. Population pattern in two counties. A: Wheat head armyworms population pattern at Pondera County, 2016. All data from 4 field sites were pooled for this graph. B: Wheat head armyworms population pattern at Choteau County, 2015.

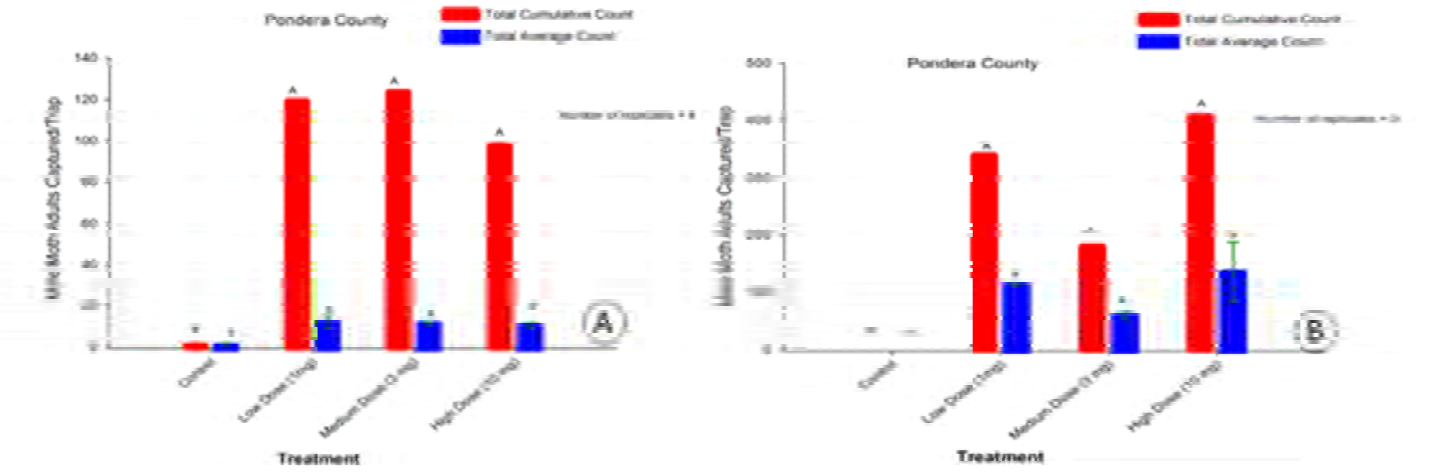

Fig. 3: Lure dose response study at Pondera County (Ledger, Conrad and Lothair). A: Lure dose response study for 2016. B: Lure dose response study for 2017. For both figures, bars bearing the same uppercase or lowercase letters are not significantly different (Tukey test, P > 0.05).

population of *D. diffusa* in the studied region. Underhill et al. (1977) reported that this pheromone attract male of *D. diffusa*. The present study showed that this pheromone acted as a strong attractant for *D. diffusa* indicating it to be the first report from Montana. Overall, pheromone traps showed greater efficiency in predicting the population of *D. diffusa* compared to the control and sweep netting.

Landolt et al. (2011) used 1 mg of this pheromone with 9 to 1 mixture of Zll-16Ac and Zll-16Ald. In the present study, the combination of both the compounds in the same ratio was used. In Pondera no significant difference between the number of adults collected in traps with three different lure doses was observed during 2016 and 2017. However, numerically greater number of male *D. diffusa* were trapped with 1 mg of pheromone in 2016 and 10 mg of pheromone in 2017 (Figure 3A, 3B). In 2017 cumulative number of adults collected in traps was overall greater compared to 2016 in Pondera County. In the year 2018, a negligible number of adults were trapped and hence data is not included in the study. In Choteau county, in the year 2016 and 2017 (combined data), there was no significant difference in the number collected in three traps but numerically trap with 10 mg of lure collected more adults (Figure 4A). Whereas in 2018, trap with 1 mg lure attracted more adults (Figure 4B). Nevertheless, in 2018 the numbers were much lower. The results obtained in both counties showed that although a numerically higher number of adults were collected with 10 mg lure, lack of statistical significant variation among the treatments indicated ineffectiveness of higher doses of this pheromone. These results can also be explained by the fact that the behavioral response of mated males can be inhibited by adding pheromone doses above the detection threshold of central neurons of an insect (Barrozo et al. 2010). Furthermore, at higher doses, sex pheromone becomes inhibitory and cannot be detected by insects. Hence, higher number of adults attracted to higher dose of pheromone could be attributed to non-attractiveness of the dose to the mated males (Barrozo et al. 2010; Showler et al. 2005). Nevertheless, low population of *D. diffusa* in 2018 in both counties indicates a reduction in population in Golden Triangle Area of Montana. A similar phenomenon is noted by Landolt et al. (2011), where low populations of *D. diffusa* was indicated as a possible reason for attracting a lower population of *D. diffusa* in Washington and Oregon states of USA.

In conclusion, this baseline monitoring data in Montana may help to alert producers to this new threat. Appropriate monitoring is must for predicting the possible damage to grains in Montana by *D. diffusa* and also by *D. terrapictalis*. Creating accessible resources for growers to forecast the presence of this pest will enable the growers to be prepared with appropriate management and farming practices. Since both *D. diffusa* and *D. terrapictalis* are not widespread to other parts of the world, all preliminary data from Pacific Northwest region will create a much required information resource about these insect pests.

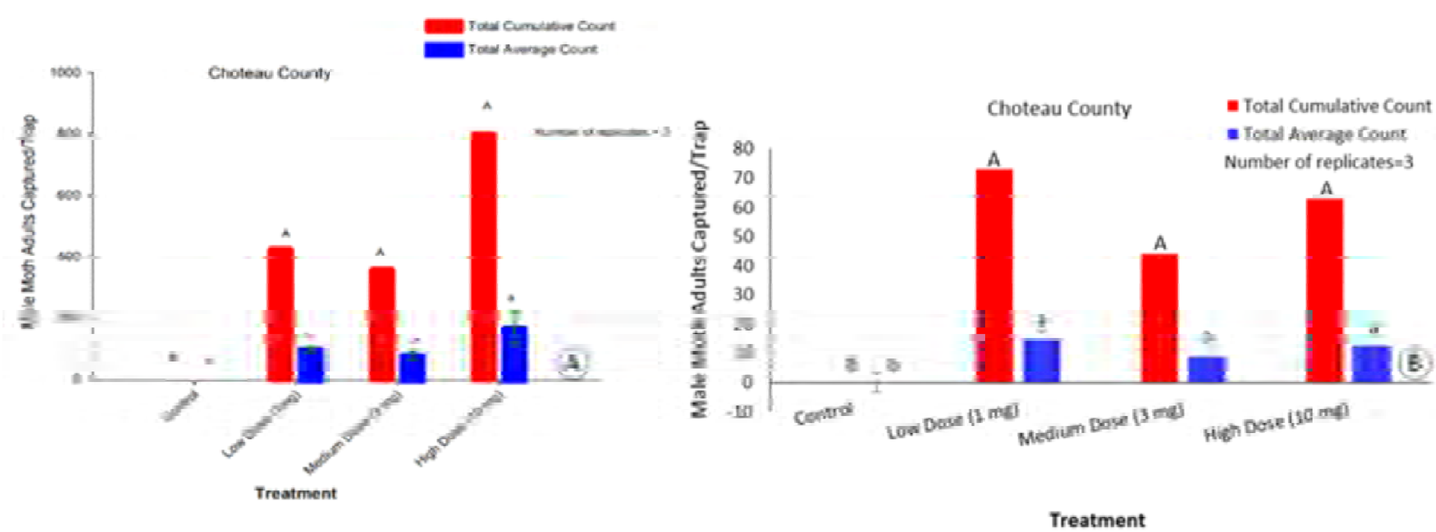

Fig. 4: Lure dose response study at Choteau County (Carter location). A: Lure dose response study data combined for 2016 and 2017. B: Lure dose response study for 2018. For both figures, bars bearing the same uppercase or lowercase letters are not significantly different (Tukey test, P > 0.05).

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