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THE USE OF OVIPOSITION ON ARTIFICIAL SUBSTRATES AS A SURVEY TOOL FOR THE FALL ARMYWORM

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ABSTRACT

Oviposition by the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), on red vinyl flags in the field afforded relatively efficient collection of egg masses and was correlated with oviposition on surrounding vegetation. Monitoring such oviposition on flags in sweet corn allowed anticipation of a population "boom." The use of oviposition on objects placed in the field as a sampling methd for fall armyworm is critically evaluated.

RESUMEN

La oviposición del gusano cogollero, *Spodoptera frugiperda* (J. E. Smith), en el campo sobre banderas rojas de vinilo rindió una colección relativamente eficiente de masas de huevos, y éstas fueron correlacionadas a la oviposición en vegetaciones cercanas. El control de la oviposición sobre banderas colocadas en maíz dulce permitió la anticipación del repentino crecimiento de la población. El método de muestreo de oviposición del gusano cogollero usando objetos puestos en el campo es críticamente evaluado.

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is somewhat indiscriminate in its selection of oviposition sites in that it deposits eggs on objects (non-host trees, houses, hanging laundry) as well as on host plants (Luginbill 1928, Porter and Hughes 1950, Claycomb 1954, Sparks 1979). This habit presents no insurmountable obstacle to hatching larvae if the mass is laid on an object above and near host plants, since the larvae spin threads and descend to the plants. During their descent they may even be carried some distance by the wind. This may be adaptive in that it disperses individuals from the location of the egg mass and thus prevents competition among sibs (Claycomb 1954).

We have found that fall armyworms (FAW) frequently oviposit on stake flags placed just above the canopy of a host crop and that FAW show a preference for flag color (Thomson and All 1982). Andrews (1980) noted that objects presenting a horizontal surface and located above a host crop canopy seem to be a preferred site for FAW oviposition.

The frequency of oviposition on these artificial substrates caused both ourselves and Andrews (1980) to suggest that this phenomenon would be useful as a survey tool for FAW. We envision a system whereby a survey entomologist can identify hot spots of oviposition activity. These hot spots could subsequently be checked for the presence of larval populations surpassing action thresholds. Currently, pheromone and light traps fulfill this early-warning role. However, their usefulness is limited by the obscure relationship of trap catches to absolute populations and future damage (Barfield et al. 1980). Admittedly, a system based on artificial oviposition substrates (AOS) would suffer similar limitations (varying preference of FAW for AOS vs. host plant, unknown schedule of mortality linking egg stage populations to larval stages), but oviposition on AOS would give us information which is logically more pertinent to damage forecasting: relative number of eggs in proximity to a target crop vs. relative number of adults (light traps) or relative number of male adults (pheromone traps).

We recognize 3 criteria for evaluating oviposition on AOS as a survey tool: 1) collection efficiency—finding egg masses on AOS must be more efficient than on crop foliage (otherwise there would be no advantage to putting AOS in the field); 2) oviposition on AOS must be reasonably correlated with oviposition on crop foliage (assuming that oviposition on crop foliage is the primary mode of infestation); and 3) the system must detect oviposition activity at levels which precede the surpassing of action thresholds. We summarize here our findings which indicate that criteria 1 and 2 can be satisfied, along with preliminary evidence supporting criterion 3. We also discuss: the possibility of estimating absolute egg mass density from oviposition on AOS; the relationship of pheromone trap catches to oviposition on AOS; and AOS design.

We have used 2 types of AOS: stake flags and pendant flags. A stake flag consists of a 10 x 13-cm piece of colored vinyl fixed to a 76-cm rigid wire, available from forestry supply companies. Since completing color preference tests (Thomson and All 1982), we have used only red stake flags. For use in survey of FAW oviposition, we generally put stake flags in the field in grid-like patches of 10-20 flags with flags separated by 1.2 m. Several of such patches are placed in a regular distribution over the area to be sampled. The flags are placed within the row of row crops. Because they are most effective if they extend above the crop canopy (Thomson and All 1982), stake flags may not be appropriate for all situations. Their advantages are that they are commercially available, easy to install in the field, and do not interfere with much agricultural machinery. Pendant flags are of our own construction, consisting of a 36 x 56-cm sheet of red upholstery vinyl tacked onto a rectangular wooden frame and suspended 2 m from the ground on a support made of wood or electrical conduit. An advantage of pendant flags is that they extend above most crops. Disadvantages are that pendant flags are not commercially available, are more costly to deploy, and must have a sturdy support which can withstand high winds. Pendant flags do interfere with agricultural machinery, sometimes necessitating perimeter placement around a field crop.

We have used pheromone traps in many of our studies. In all cases, these have been Pherecon 1C traps (Zoecon) baited with (Z)-9-dodecen-1-ol acetate.

Collection Efficiency and Correlation with Oviposition on Crop Foliage

Our studies have compared oviposition on flags (flag oviposition) and on crop foliage (crop oviposition) in sweet corn, grain sorghum, soybeans and fescue. Observations made concurrently in all the crops show that flag oviposition reflects the relative activity of FAW among different crops (Fig. 1). Flag oviposition will even reflect oviposition preference exhibited by FAW over a relatively small spatial scale: among adjacent 8-row x 20-m plots of field corn, sorghum and soybeans (Thomson 1981). Because of generally low activity of FAW in crops other than corn, a quantitative analysis of collection efficiency and correlation between crop and flag oviposition has been performed only for observations made in corn.

The relationship between flag and crop oviposition observed in sweet corn is depicted in Fig. 2. Overall correlation between flag and crop oviposition in five plantings of sweet corn were: 0.72 between stake flags and pendant flags; 0.58 between pendant flags and crop oviposition; and 0.46 between stake flags and crop oviposition. As mentioned above, a likely problem with using oviposition on artificial substrates as a survey tool is variance in the relationship between crop and flag oviposition as weather or crop conditions change. This type of an effect appears to be shown in Figure 2C: egg mass counts on stake flags initially exceeded counts from plant samples, but this relationship switched after the first 2 weeks, perhaps due to the increase in oviposition sites on the crop foliage as the corn increased in size. Oviposition on the pendant flags did not show this effect; it may be that the height of the pendant flags relative to the crop prevented any interference from crop foliage. Such problems constrain our ability to make precise estimates of egg mass densities on crop foliage from observations of flag oviposition (see below), but we feel that the evidence presented in Fig.

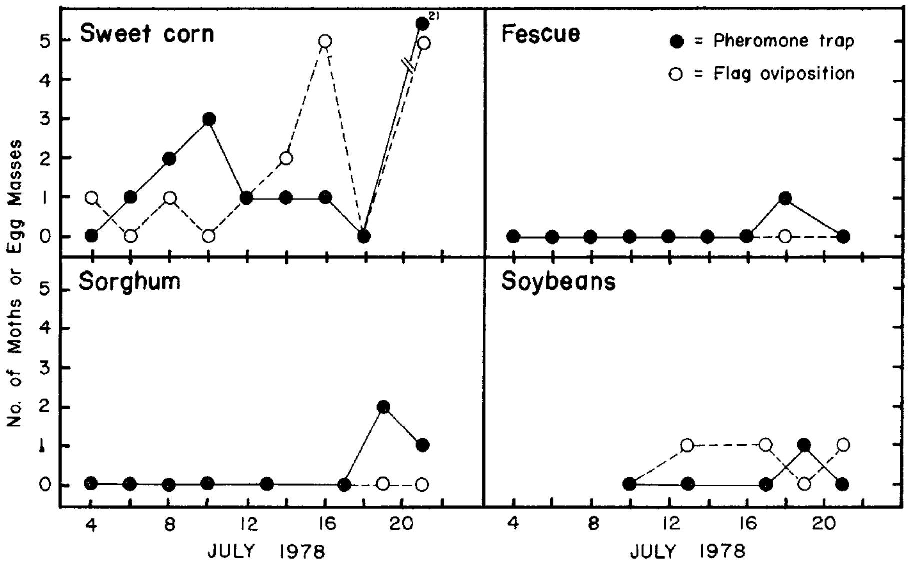

Fig. 1. Fall armyworm activity in 0.5-2.0-ha fields near Athens, GA. At each site were monitored one pheromone trap (at field's edge) and a patch of 144 stake flags (within field, 18 flags each of 8 different colors). Equivalent searching in the foliage of all fields yielded egg masses and larvae from the sweet corn only.

1 and 2 demonstrate that flag oviposition is reasonably well correlated with crop oviposition such that the information would be valuable to survey entomologists and pest managers.

The data presented in Fig. 2 were analyzed to compare the collection efficiency of the sampling methods used (Table 1). Plant observations were less efficient at finding egg masses; they were also considerably more difficult to accomplish, requiring much stooping and eye-strain. Our experience in other crops (fescue, soybeans, sorghum, cotton) has been that FAW egg masses are most easily found by searching stake or pendant flags. It is important to note that the plant searching method we used provided qualitatively different information than the flag methods, since the plant observations can easily be converted to an absolute measure of egg mass density in crop foliage, whereas the flag methods yield only a relative measure. Also, Table 1 does not include the up-front costs for materials and set-up required by the flag systems. These costs are minimal for stake flags, which are commercially available at approximately $6.00/100, and are easily installed in the field. Pendant flags are more costly than stake flags primarily because they are not commercially available.

Anticipating Action Thresholds

Flag oviposition will be useful as a survey tool if it can consistently detect FAW oviposition activity at levels which precede the development of economically important larval populations. This might best be tested by incorporating observation of flag oviposition (flag sampling) into a pest

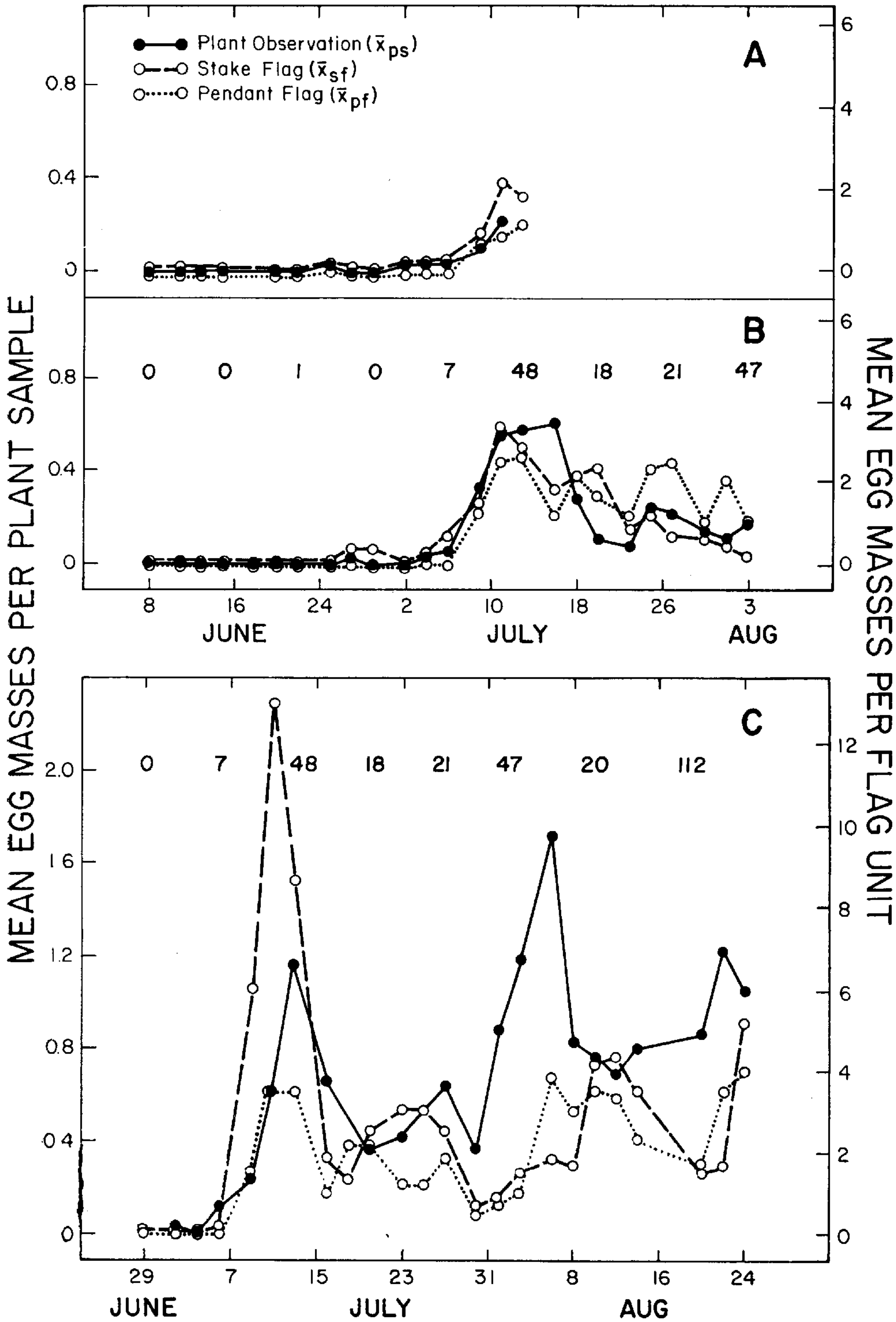

Fig. 2. Fall armyworm activity in 3 adjacent 0.3-ha plots of sweet corn near Athens, GA. Planting dates were: A, 18 April; B, 21 May; and C, 20 June 1979. One plant sample = *in situ*, whole plant search of 3 consecutive plants in a row. One flag unit = 1 pendant flag or a patch of 16 stake flags. Each point represents the mean of 36 plant samples or 6 flag units. Numbers within the figure represent total catch from 3 widely spaced pheromone traps located outside of the study site, but within 1 km.

TABLE 1. COMPARISON OF SAMPLING METHODS[1] FOR EGG MASSES OF THE FALL ARMYWORM IN SWEET CORN.

Method	Mean egg masses per observation ± SE	Cost per observation[4] (min.) CS	Egg masses collected per minute	Mean relative variance[5] ± SE RV	Relative net precision 100/(RV•CS)
Plant observation[2]	25.9 ± 2.0	130	0.2	25 ± 1.6	0.03
Stake flag[3]	16.6 ± 1.8	15	1.1	33 ± 2.2	0.20
Pendant flag[3]	13.9 ± 1.3	15	0.9	35 ± 2.1	0.19

[1]Only includes observations from days where all 3 methods discovered egg masses, n=65.
[2]Each observation equals egg masses found from whole plant search of 36 randomly selected plant samples (3 consecutive plants in a row).
[3]Each observation equals egg masses found on 6 flag units (1 flag unit = a patch of 16 stake flags or 1 pendant flag).
[4]Does not include cost for acquiring and setting up flags in the field.
[5]RV = $(s_x/\bar{x})$ (100), where $\bar{x}$ = mean egg masses per plant sample or flag unit discovered on an observation day, s_x = standard error of the mean.

scouting program for several years on an experimental basis. A flag sampling system has not been tested conclusively in this manner. We present here preliminary evidence from our experience in sweet corn.

In sweet corn, scouting programs oriented towards detecting action thresholds are generally not cost effective (Barfield et al. 1980). However, observation of FAW activity in "indicator" fields of corn has been used to monitor infestations on a regional basis (Hunt 1980). Flag sampling in this system might be useful if it could detect FAW activity substantially before larvae or damage are noticed. This would give managers and other interested parties within the region more time to formulate and carry out a response.

Our flag sampling did not detect oviposition activity prior to the development of low level infestations in sweet corn: for example, in Fig. 2B, 20% of the corn plants were infested with late instar larvae on 25 June. Pheromone trap catches were also inadequate in this regard as has been observed previously (Sparks 1980). However, serious infestations were preceded by flag oviposition: in Fig. 2C, 0% plants were infested with larvae on 9 July, the day on which a sharp increase in oviposition activity was observed; 7 days later, 95% of the plants were infested with FAW larvae (Thomson 1981). Such timely warning of a "boom" population is likely to be of interest to managers of crops susceptible to FAW. Replication over several years of these studies and similar studies in other crops is needed to determine if flag sampling is of consistent utility.

OTHER CONSIDERATIONS

Some other aspects of flag sampling should be briefly discussed. These are: 1) estimating absolute density of FAW egg masses from flag oviposition; 2) the relationship between flag oviposition and pheromone trap catches; and 3) AOS design.

The number of egg masses on flags in the field is a relative measure of

FAW egg density. If this relative measure could be converted to absolute egg density, the study of population processes would be facilitated, since egg stage densities could then be compared to absolute densities of other life stages (Southwood 1978). We have attempted to derive a mathematical relationship between flag and crop oviposition (easily converted to absolute egg mass density) in sweet corn, but have had unsatisfactory success because of our inability to measure crop oviposition precisely (Thomson 1981). Searching for egg masses on crop foliage has been costly, yielding low numbers of egg masses and thus imprecise estimates of density (mean relative variance = 25%, Table 1). A flag oviposition estimator of absolute density can not be expected to be more precise than the crop oviposition data used for calibration. Our estimator had a minimum standard error of approximately 35% of the estimate and approached 100% at low population levels (Thomson 1981). In principle, flag oviposition can be converted to an estimate of absolute egg density, but this may not be useful until the sampling problem of directly estimating absolute density is solved. Given this, the value of flag oviposition data will be evident only from sequential observations, or observations spread out over space such that population trends (Fig. 1, 2) and distribution (Fig. 1) are depicted. Single, isolated observations of flag oviposition are not very meaningful.

In our experience, pheromone trap catches and flag oviposition have shown similar patterns of FAW activity and we have no evidence that flag oviposition depicts FAW pressure in a particular crop better than pheromone trap catches. In Fig. 1, both sampling methods depict similar activity between crops (apparent lack of correlation between pheromone trap catch and flag oviposition within each crop was probably due to chance variation, since counts were so low). In Fig. 2, correlation between pheromone trap catch and flag oviposition is good. However, we suspect that flag sampling can detect the spatial distribution of FAW oviposition on a finer scale than pheromone traps. This has not been tested. In theory, flag oviposition ought to be more representative than pheromone trap catches of FAW pressure on a particular crop: flag oviposition represents FAW eggs present within the boundaries of the crop, ostensibly because female moths responded to the crop as host plants; pheromone trap catches represent males flying in response to female pheromone and not directly in response to the crop. Further work is needed to determine if these ideas have any practical significance.

There has been little systematic investigation of the effect of design (shape, size, materials) on the attractiveness of AOS for FAW oviposition. We have tested only two basic designs: the pendant flag and stake flag. A research priority should be to determine if a more attractive design can be devised. We have observed that the majority of egg masses on our substrates have been deposited on undersurfaces: under folds in the stake flags, and on the downward facing horizontal surfaces of the wooden frame and support of the pendant flags. This agrees with previous observations of FAW oviposition on artificial substrates (Andrews 1980) and host plants (Sparks 1979, Pitre et al. 1983, Thomson and All 1983). We have also found that red color and location just above the crop canopy gives the best collection efficiency for stake flags (Thomson and All 1982). Therefore, at least 3 factors should be considered when developing new AOS: color, height above crop canopy, and the presence of downward facing horizontal surfaces. Consideration should also be given to practical matters such as cost of materials, durability, cost of installation in field, and compatibility with agricultural machinery. Identifying an optimum design for AOS is a research priority which should logically precede further investigation of their utility as a survey tool.

CONCLUSIONS

Our observations indicate that searching AOS can be an efficient means of collecting FAW egg masses and that counts of FAW egg masses on AOS are representative of FAW oviposition activity in the field. We believe this phenomenon can be used to monitor FAW activity and have demonstrated that a sampling system based on AOS can give early warning of "boom" populations in sweet corn. We suggest that the utility of AOS sampling systems be tested in other crops such as pasture grasses, sorghum and alfalfa (Barfield et al. 1980) which are likely to benefit from a scouting program for FAW. A research priority should be the development of an optimum AOS design for attracting FAW oviposition. Such a study could result in the development of a more "efficient" AOS and thus increase the chances that oviposition on artificial substrates will become an important tool for monitoring FAW populations.

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DIFFERENTIAL GROWTH RESPONSES OF FALL ARMYWORM[1] LARVAE ON DEVELOPING SORGHUM SEEDS INCORPORATED INTO A MERIDIC DIET[2]

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ABSTRACT

Seed of developing sorghum, *Sorghum bicolor* (L.) Moench, mixed in a substandard meridic diet, was fed to larvae of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith). Larval weight differences were measured at 8-14 days after infestation. Differences between weights of FAW larvae fed NK 'Savanna 5' and 'Funk 5245' were found at the following stages of plant development: milk stage, soft dough stage, hard dough stage, high moisture dry seed, and low moisture dry seed. The larvae that were fed diets of NK 'Savanna 5' were consistently smaller over all stages tested. Forty to 80 g of immature or mature seed per diet resulted in detectable differences between the 2 sorghum genotypes. An evaluation of 10 randomly selected sorghums mixed in the diets produced weights of larvae that showed significant differences among cultivar responses at the milk stage and dry seed stage. The FAW larvae that were fed diets of NK 'Savanna 5' and 'TAM 2566' were consistently smaller over several tests as compared with other sorghums evaluated. A nonsignificant relationship was found between FAW feeding responses on the fresh-milk stage cultivars mixed in diets and feeding responses on those diets made from frozen milk-stage seed. Indications were that the smaller larvae were produced on resistant sorghum cultivars and that this may have been due to a lack of adequate nutrients. No apparent relationship was found between tannin content of the dry seed and FAW growth responses.

RESUMEN

Larvas del gusano cogollero (FAW), *Spodoptera frugiperda* (J. E. Smith), se alimentaron con semillas de sorgo, *Sorghum bicolor* (L.) Moench, mezcladas con una dieta artificial inferior. Las larvas se pesaron de 8 a 14 días después de la infestación. Hubieron diferencias entre los pesos de las larvas FAW alimentadas con 'NK Savanna 5' y con 'Funk 5245' en las siguientes etapas de desarrollo de las plantas: la de leche, la de masa suave, la de masa dura, la de smilla seca de alta humedad, y la de semilla seca de

[1]Lepidoptera: Noctuidae.

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