OVIPOSITION HABITATS OF *PSOROPHORA COLUMBIAE* IN SOYBEAN FIELDS OF A TEXAS RICELAND AGROECOSYSTEM[1]

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ABSTRACT. Soil samples were collected over a 2½-year period from microhabitats in fields planted to soybeans in Chambers County, TX, to study the oviposition behavior of *Psorophora columbiae*. An analysis of egg collection data gathered from the processing of 1,098 soil samples suggested that, during wet years, *Ps. columbiae* eggs tend to be scattered throughout soybean fields. During dry years, a greater abundance of eggs occur in the low areas of these types of fields. The data also suggested that oviposition by *Ps. columbiae* is concentrated in soil near the base of soybean plants rather than in open furrows between the rows of plants.

INTRODUCTION

The relative importance of rice fields and pastured fields as oviposition sites for the floodwater mosquito species, *Psorophora columbiae* (Dyar and Knab), in southern riceland agroecosystems has been fairly well documented (Schwardt 1939; Horsfall 1942, 1955; Meek and Olson 1976, 1977; Olson and Meek 1980). More recently, the potential importance of soybean fields as yet another source of oviposition sites for this species in certain parts of the southern rice-producing region of the United States was reported by Welch et al. (1986).

Specific microhabitats used most commonly by *Ps. columbiae* females as oviposition sites in rice fields and pastured fields have also been defined and described for southern riceland systems (see references above). However, prior to the current study, little or no information existed on the nature of the microhabitats used by *Ps. columbiae* in fields planted to row crops such as soybeans. In this regard, *Ps. columbiae* egg distribution patterns in soybean fields were studied over a 2½-year period (1979-81) in a rice-producing region along the upper Gulf Coast of Texas. During the course of this study, the microhabitats actually used by *Ps. columbiae* females as oviposition sites in these kinds of fields were defined and are the subject of the information presented herein.

MATERIALS AND METHODS

The 5 soybean fields used in this study were located in Chambers County, TX. Four of the fields were in a Beaumont-Morey-Lake Charles soil association, which is characterized as being level or nearly level, acid to neutral, clayey and loamy soils with very slow permeability (Crout 1976). Such an association allows water to stand for long periods after heavy rainfall (Fig. 1). One of the study fields (33.8 ha) with this soil association was planted during the 1979 growing season and will be referred to as Field 2-Soybean. Another field (18.5 ha) was planted during 1980 and will be referred to as Field 5-Soybean. Two other fields in the Beaumont-Morey-Lake Charles soil association, planted during the summer of 1981, will be designated as Field 1-Soybean (70.8 ha) and Field 8-Soybean (49.7 ha).

The fifth field (Field 4-Soybean) contained 32.1 ha and was planted during the summer of 1980. This particular field was located in a region of the county with a Vaiden-Acadia-Calhoun soil association. This association is characterized as being nearly level with depressions where water stands for long periods after heavy rains (Crout 1976).

Numerical designations were given to the soybean study fields during a more expansive investigation of rice and pastured fields as well as soybean fields in regard to their relative importance as sources of oviposition sites for *Ps. columbiae* (Welch et al. 1986). For this reason, the field numbers given herein do not reflect the chronological sequence in which they were used for this particular study.

Four sampling areas were established in Field 2-Soybean in 1979. These areas were 30.5 m-wide bands extending across the width of the field perpendicular to the east-west direction of the rows. Sample Area 1 (SA 1) was located 305 m from the east end of the field and the other sampling areas (SA 2 - SA 4) were spaced 305 m apart in westward direction away from SA 1, with SA4 being at the highest field elevation.

Four 3-m^2 sample areas were established in each of the 2 fields used during 1980 (i.e., Field 4-Soybean and Field 5-Soybean). Sample Area 1 (SA 1) in Field 4-Soybean was located in a low spot in the field 43 rows in from its southern edge. Sample Area 2 (SA 2) was located north-

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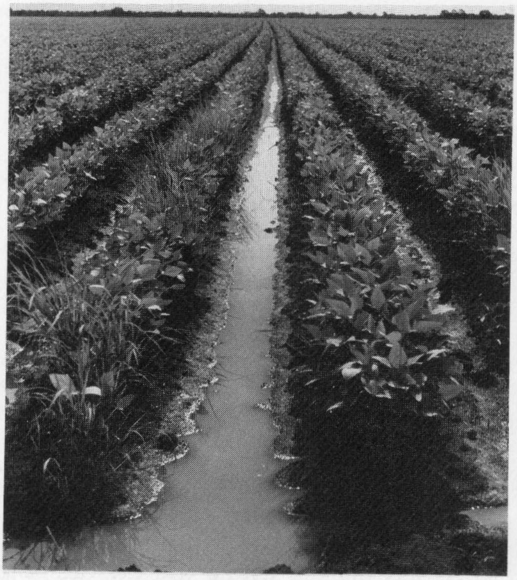

Fig. 1. Standing water in a field planted to soybeans in a Beaumont-Morey-Lake Charles soil association in Chambers County, TX.

east of SA 1 in a slightly more elevated, fallow area near the center of the field. Sample Area 3 (SA 3) was located in the vicinity of a drainage ditch at row 170 near the west end of the field. Sample Area 4 (SA 4) was in a high area of the field at row 335 northeast of SA 3. In the case of Field 5-Soybean, Sample Area 1 (SA 1) was located in a low area at the intersection of row 132 of the field and a former rice field levee near the east end of the field. Sample Area 2 (SA 2) was in a higher area of the field at row 125 approximately 539 m from the west end. Sample Area 3 (SA 3) was in another low area at row 16 (6 m from the west end of the field) and Sample Area 4 (SA 4), also in a low area, was at field row 110 (18 m from the west end).

Two sampling areas were established in each of the 2 fields used during 1981 (i.e., Field 1-Soybean and Field 8-Soybean). Sample Area 1 (SA 1) in Field 1-Soybean was in a high region and Sample Area 2 (SA 2) was in an adjacent low region of the field. Both sampling areas were approximately 150 m from the east corner of the field. Sample Area 1 (SA 1) in Field 8-Soybean was also located in a high, well-drained region of the field, whereas Sample Area 2 (SA 2) was in a low, poorly drained region. SA 1 and SA 2 in this field were ca. 10 m and 150 m into the field from the southeast side, respectively.

A total of 1,098 soil samples was collected from the soybean field sampling areas included in this study. The period over which soil samples were periodically taken from the various sampling areas extended from June 1979 through September 1981. Specific sites within each sampling area from which soil samples were to be taken were selected the first year (1979) by giving each soybean row in Field 2-Soybean its own numerical designation and then selecting the row to sample using a table of random numbers. During subsequent years of the study, specific sampling sites within each sample area were selected with the aid of aerial color infrared photographs of the study fields. In this case, each soil sampling site was selected on the basis of differences in appearance of various locations within the particular sampling area depicted on photographs of the field being studied. Also, during 1981, soil samples within each of the sampling areas were taken along transects running perpendicular to the soybean rows so as to determine the mosquito egg distribution patterns in relation to the position of the plants.

Soil samples (15.2 x 15.2 x 2.5 cm each) were collected from each sampling area in a manner similar to that described by Horsfall (1976). Soil moisture content at each sampling site was estimated by the hand-squeeze method of Box and Bennett (1959) as modified for use in mosquito egg surveys by Olson and Meek (1977). Upon their return to the laboratory, the soil samples were each subjected to the egg/soil separation technique described by Horsfall (1956), and mosquito eggs, if present, were counted and identified to species using a dissecting stereomicroscope and taxonomic keys to mosquito eggs (Ross and Horsfall 1965). Unidentifiable eggs were hatched and larvae were reared to the fourth instar, identified and counted.

Chi-square statistical analyses were performed using soil-sample egg collection data to determine *Ps. columbiae* egg distribution patterns within the various soybean fields sampled during the course of the study. The null hypothesis tested was: Oviposition in Sample Area 1 = Sample Area 2 = Sample Area 3 = Sample Area 4, or oviposition in the high area = oviposition in the low area, depending on the nature of the sampling areas involved. The alternative hypothesis was: At least 1 of the observed sample area counts was different from the hypothesized counts, or a preference was observed in oviposition between sample areas. In the case of egg data gathered on soil samples taken from a sample area more than once during November through May of a given sampling period, these data were pooled for analysis since the eggs were ones which had been deposited in the sample area by the previous season's mosquitoes and did not represent new egg populations, but rather just a variation between samples taken of the same static egg population.

RESULTS

Data regarding the average numbers of *Ps. columbiae* eggs per sample and the frequency of egg-positive samples for soil samples from the sampling areas in Field 2-Soybean are summarized in Fig. 2. The average relative frequency of positive samples ranged between 0.1 and 0.2 and the mean number of eggs per sample ranged between 3.6 and 9.8 for these sample areas. Chi-square analysis of these data indicated no difference between the relative frequencies of positive samples between the 4 sample areas. However, a highly significant difference ($P < 0.005$) did exist in the abundance of eggs. Sample Areas 1–3 had higher numbers of eggs and SA 4 had lower numbers of eggs per sample than was expected.

Monthly and total average numbers and relative frequencies of *Ps. columbiae* eggs for SA 1–3 of Field 4-Soybean are presented in Fig. 3. The average relative frequency of positive samples for these 3 sample areas ranged between 0.04 and 0.1 with mean numbers of eggs per sample ranging between 2.0 and 4.0. No positive samples were collected from SA 4 and Field 4-Soybean during the study. Chi-square analysis of the collection data from this field indicated the difference in the frequencies of positive samples was not significant, but that a significant difference ($P < 0.005$) existed in the numbers of eggs per sample. More eggs were collected from SA 1 than was expected had oviposition rates been equal between the 4 sample areas in Field 4-Soybean.

Data regarding the egg-positive samples taken from SA 1, 3 and 4 of Field 5-Soybean are presented in Fig. 4. No positive samples were collected from SA 2 during this study. The average relative frequencies of egg positive samples for the sample areas where eggs were collected ranged between 0.05 and 0.1 and the mean average number of eggs per positive sample ranged between 1.0 and 1.7. The only difference discerned by Chi-square analysis of collection data from Field 5-Soybean was in the total numbers of eggs per sample. Significantly more eggs per sample ($P < 0.05$) were collected from SA 1 and SA 3 than would be expected had oviposition in all sample areas been equal.

Fig. 5 presents the results of egg collection data for Field 1-Soybean. The average relative frequencies of positive samples for the low sample area in this field were 0.1 in June and 0.3 by September 1981, while the mean number of eggs per positive sample rose from 1.4 in June to 1.7 in September. The average frequencies of positive samples in the high sample area in this field ranged between 0.1 (June) and 0.4 (September) and the mean number of eggs per sample ranged between 1.3 (June) and 1.7 (September). Chi-square analysis of these data indicated no differences ($P > 0.05$) in either the frequencies of positive samples or the numbers of eggs per sample between the low and high areas of Field 1-Soybean suggesting that oviposition by *Ps. columbiae* in this particular field was the same for both areas during the summer of 1981.

Average numbers of eggs and relative frequencies of positive samples collected from the 2 sample areas in Field 8-Soybean are presented in Fig. 6. The frequencies of positive samples ranged between 0.3 (high area) and 0.7 (low area) and the mean numbers of eggs per sample ranged between 5.3 (high area) and 8.1 (low area). Chi-square analysis of these data indicated a significantly greater number of eggs per sample were collected in the low area of this field than were collected in the high area ($P < 0.005$). However, there were no significant differences between these sampling areas as far as the frequency of egg-positive samples was concerned.

Egg collection data for soil samples taken along transects perpendicular to the rows in Field 1-Soybean are summarized in Table 1. The frequencies of egg-positive samples for the areas at the base of plants and between plants rows ranged from 5 to 11 and from 0 to 6, respectively, while the ranges for the numbers of eggs per samples were 7 to 119 and 1 to 19, respectively. Chi-square analysis of these data indicated significantly more eggs per sample were collected from the areas at the plant bases than from those in between the plant rows ($P < 0.005$).

Eggs of 2 other mosquito species were detected in samples taken during his study. *Psorophora ciliata* (Fabricius) eggs were present in 2 samples taken in 1980. Among the soil samples collected during 1981, one was positive for *Ps. ciliata* eggs and 3 were positive for *Aedes vexans* (Meigen) eggs.

DISCUSSION

Information and results obtained during this investigation add to the further understanding of oviposition of *Ps. columbiae* within microhabitats of southern riceland agroecosystems. Data collected during this study suggest that during wet years, eggs of this species tend to be distributed throughout fields planted to soybeans. Analysis of sample data from Field 2-Soybean (Fig. 2) sampled during the wet summer (729 mm of precipitation during June–September) of 1979 (see Welch et al. 1986 for a discussion of weather) showed no statistically significant difference in the relative frequency of positive samples between the 4 sample areas, although the

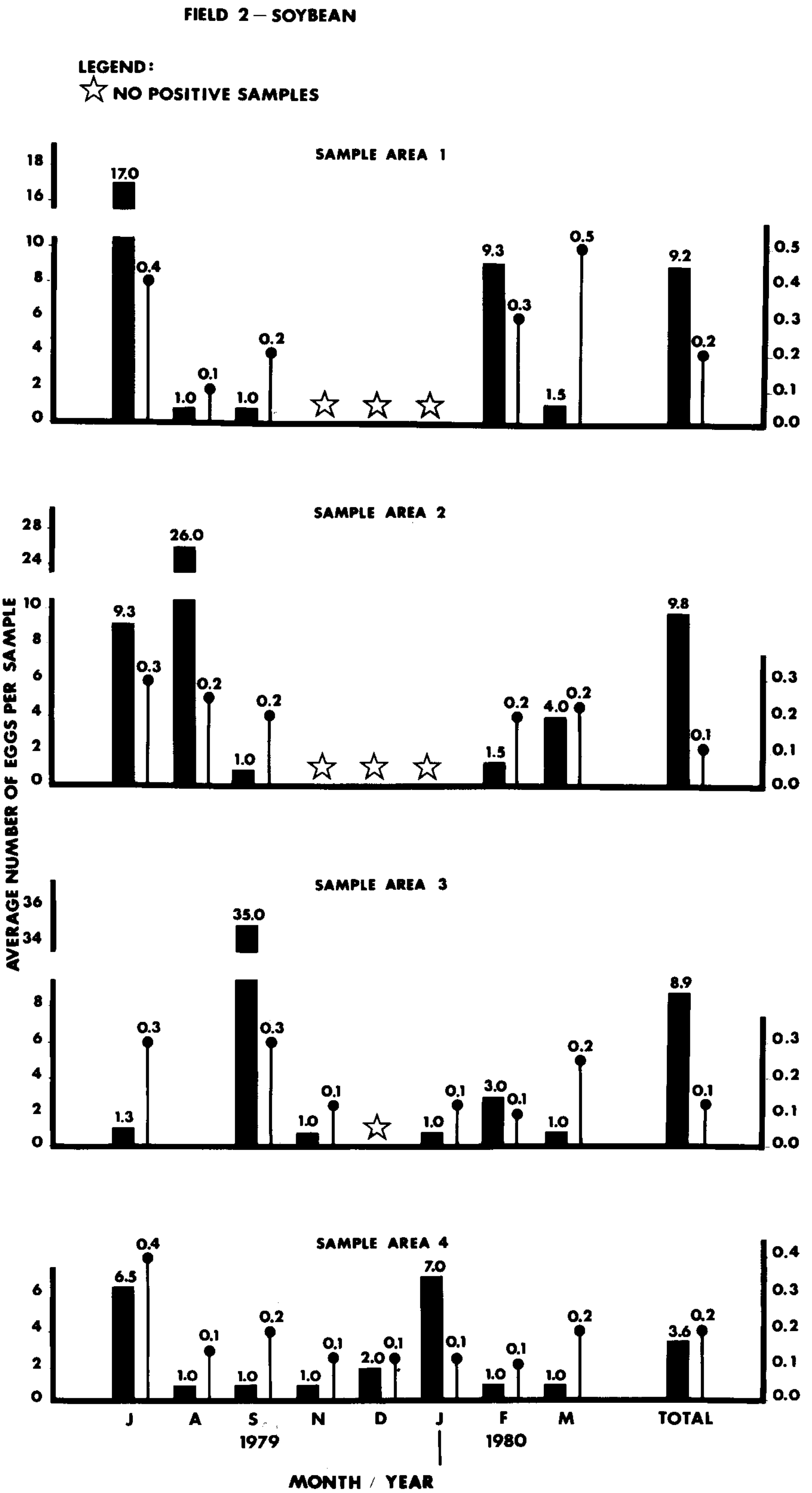

Fig. 2. Average numbers and relative frequencies of *Psorophora columbiae* eggs occurring in soil samples collected over the periods July–September and November–December 1979, and January–March 1980 from 4 sample areas in Field 2-Soybean.

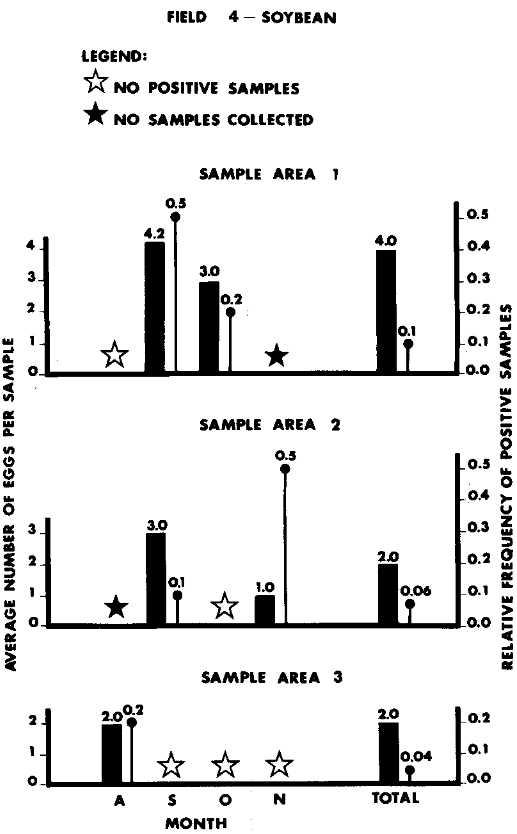

Fig. 3. Average numbers and relative frequencies of *Psorophora columbiae* eggs occurring in soil samples collected over the period August–November from 3 sample areas in Field 4-Soybean.

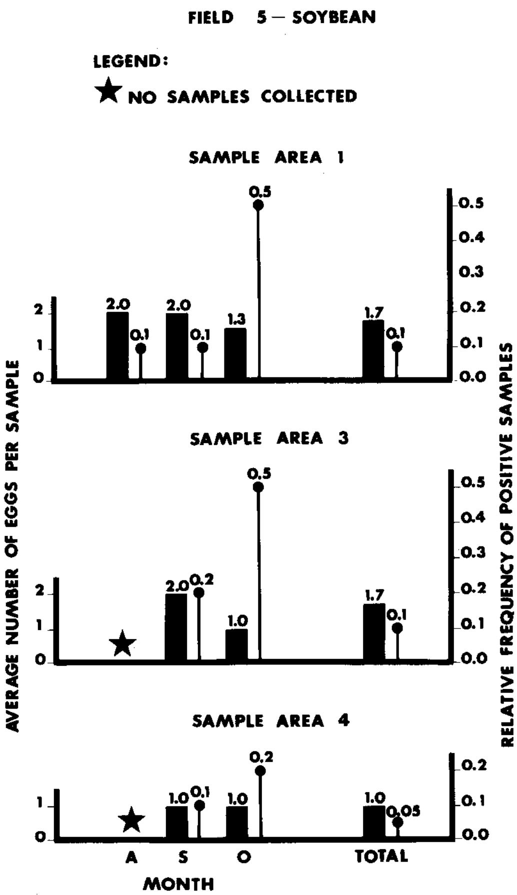

Fig. 4. Average numbers and relative frequencies of *Psorophora columbiae* eggs occurring in soil samples collected over the period August–October from 3 sample areas in Field 5-Soybean.

average numbers of eggs per sample were greater in SA 1, 2 and 3. Also, egg-positive samples taken within each of the 30.5-m-wide sample areas located in Field 2-Soybean seemed to have no distinct pattern as to their location in the field. Similar results were obtained for Field 1-Soybean during the wet summer (950 mm of precipitation during June–September) of 1981 when no significant difference in either frequency of positive samples or eggs per sample occurred between the samples taken in the high and low areas of the field (Fig. 5).

Low areas or localized depressions appear to be important as oviposition habitats for *Ps. columbiae* in fields planted to soybeans during dry years such as occurred in 1980 (505.5 mm of precipitation during June–September) during our study (Welch et al. 1986). Although no statistical difference was evident in the frequency of positive samples taken from the 4 sample areas of Field 4-Soybean sampled during 1980 (Fig. 3), no positive samples were collected from SA 4 which was in a high area of the field. There was, however, a significant difference in the abundance of eggs in samples taken from the various sample areas, with more eggs being collected from SA1 (a low area in the field) than from the other higher elevated sample areas. Similar results were obtained from sample areas located in Fields 5- and 8-Soybean (Fig. 4 and 6, respectively).

Several characteristics may contribute to the attractiveness of soybean fields as oviposition habitats for *Ps. columbiae*. These fields provide a large surface area of disturbed soil that is available for oviposition. Such is not often the case with flooded rice fields, where frequently only the levees are available for oviposition (Olson and Meek, 1977, 1980). These same authors noted that virtually any disturbed soil having a moisture content of 75–100% field capacity is subject to oviposition by *Ps. columbiae*. During periods of heavy rainfall, nearly the entire ex-

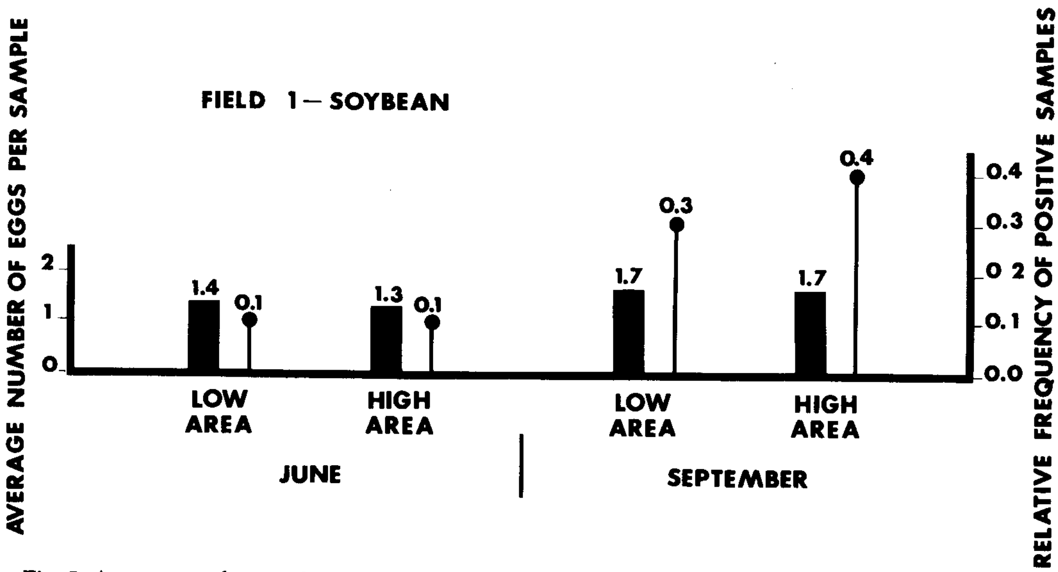

Fig. 5. Average numbers and relative frequencies of *Psorophora columbiae* eggs occurring in soil samples collected in June and September 1981 from a low and high area in Field 1-Soybean.

Table 1. Collections of *Psorophora columbiae* eggs from soil samples taken along transects perpendicular to plant rows in soybean fields in Chambers County, TX during 1981.

		Location of soil sample					
		At plant base			Between plant rows		
Date	Field	No. of samples	No. of pos. samples	No. of eggs	No. of samples	No. of pos. samples	No. of eggs
June 24	1-SB	8	5	7	42	0	0
June 25	1-SB	10	4	4	40	1	2
Sept. 23	1-SB	15	10	57	15	5	19
Sept. 23	8-SB	17	11	119	13	6	11
Totals		50	30*	187*	110	12	32

* $P < 0.005$.

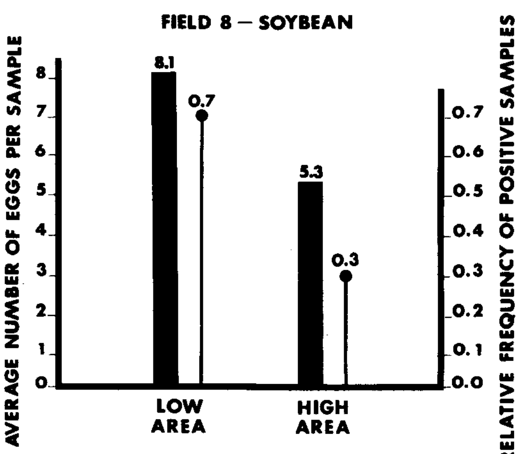

Fig. 6. Average numbers and relative frequencies of *Psorophora columbiae* eggs occurring in soil samples collected in September 1981 from a low and high area in Field 8-Soybean.

panse of a soybean field in the upper Gulf Coast area of Texas can have a soil moisture content of 75–100% field capacity due to the poor permeability and drainage of the local soils in this area of the state. Such weather and soil moisture conditions would make soybean fields attractive to female mosquitoes seeking the proper soil moisture conditions for the deposition of their eggs; and as observed in our study, the eggs would probably be widely distributed over the field. Results of a study by Rankin and Olson (1985) tend to support our observations in that they indicated the frequency of occurrence and relative abundance of *Ps. columbiae* eggs were significantly higher in fields subjected to full-pan evaporation rates of sprinkled water (where soil moisture content is maintained at the 75–100% level for long periods of time) as compared to fields irrigated at half-pan and quarter-pan rates.

Another factor making soybean fields attractive to *Ps. columbiae* females is the relatively exposed soil being protected by a low herbaceous canopy of bean plants. Horsfall (1963) reported that low herbaceous foliage provides aggregation sites for adult mosquitoes since it shelters them from excess light, dryness and wind. In the current study, *Ps. columbiae* adults were often observed in the study fields and usually took blood meals from field personnel collecting soil samples. Horsfall (1963) also stated that accumulation of great numbers of eggs is possible when aggregation sites are in close proximity to those suitable for oviposition. Such conditions prevail in soybean fields.

Gently sloping banks combined with a proper layer of plant debris are another set of factors tending to support the deposition of large numbers of floodwater mosquito eggs, due to these factors supporting the persistence of soil moisture (Horsfall 1963). These factors are certainly present in soybean fields because the soybeans are planted in rows where the soil elevation beneath the plants is higher than that of the soil in the middle of the row. Also, the surface of the soil in these fields is generally covered by a layer of senescent leaves that fall during the growing season.

Minute cracks in disturbed, moist soil have also been implicated as preferred oviposition sites for *Ps. columbiae* (Schwardt 1939, Horsfall 1955). Bosworth[4] reconfirmed this for Texas populations of this species during a laboratory study where cracks and small holes in clay and silt loam soils were found to be the primary oviposition sites for *Ps. columbiae* females exposed to different potential oviposition substrates. The availability of such cracks and crevices in the disturbed, exposed soil of the fields planted to soybeans seems almost limitless in an area where clayey and loamy soil such as occurs in Chambers County, TX.

As for the numbers of mosquito eggs found in any one area of a soybean field, Horsfall (1963) stated that soil moisture and its persistence in a given area play a significant role in determining the numbers of eggs ultimately deposited at a particular location over an extended period of time. This would explain the frequently higher abundance of eggs obtained from the sample areas situated in localized depressions in fields planted to soybeans during this study. The low areas receive runoff of rain from the higher areas of the field; and because of the poor water permeability characteristic of the soil types in the area, these lower areas would hold the water and thus maintain the 75–100% soil moisture conditions attractive to *Ps. columbiae* for egg deposition for a longer period of time than would be the case for the higher areas of the field.

In summary, results described herein suggest cultivated soybean fields in Texas are important oviposition habitats for *Ps. columbiae* in the rice-producing area of the state. During wet years, essentially the entire field may have the soil moisture conditions favored by ovipositing females of this species and oviposition may occur over the whole field or at least a large portion of it. During dry years, low areas and localized depressions in fields planted to soybeans receive runoff and hold moisture longer than high areas, thus providing soil conditions that are more conducive to higher egg populations occurring in the lower areas of a given soybean field. Regardless of location in the field, the area under the soybean plants appears to be more attractive to egg-laying females than do areas between rows of bean plants.

The potential role of soybean fields as important sources of oviposition sites for *Ps. columbiae* populations in the rice-growing areas of the upper Texas Gulf Coast becomes even more significant when one considers the total amount of land currently being planted to soybeans each year in this area of the state. Over the years spanned by our study (i.e., from 1979 to 1981), the amount of land devoted to soybean production in the Texas coastal rice-producing region ranged between 425,000 (1979) and 378,000 (1981) acres. The estimated total acreage included in the Texas coastal rice-growing region is ca. 1.5 million acres; thus, over a fourth of the agricultural land in this region is being devoted to soybean production and otherwise is available to *Ps. columbiae* for use as oviposition sites, provided the soil moisture conditions are met.

The actual role played by soybean fields in the dynamics of *Ps. columbiae* populations occurring in the Texas coast rice-growing areas will vary. In some years, these fields may serve as "traps" and in other years, they may serve as "sources" of mosquitoes depending on the amount, time of occurrence and length of rainfall. For example, the soybean fields would serve as traps, if, after a rainfall in the warmer months of the year, no temporary pools of water form to stimulate hatching of the eggs deposited in these fields or if temporary pools which *do* form dry up before the mosquitoes can reach the adult emergence stage of their development. Soybean fields would serve as sources of mosquitoes when rainfall is sufficient to cause pools of standing water to remain for 3–4 days or at least long enough for the mosquitoes to reach the adult emergence stage. Both these situations have been observed to occur in the riceland agroecosystems of the upper Texas Gulf Coast.

[4] Bosworth, A. B. 1980. A study of the chorion of the egg of *Psorophora columbiae* (Dyar and Knab) (Diptera: Culicidae). Ph.D. Dissertation, Texas A&M University, College Station, TX., 158 pp.

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