OBSERVATIONS ON MOVEMENT OF SPITTLEBUG ADULTS[1]

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ABSTRACT - Heights at which spittlebugs travel was monitored by trapping adults on 3 m tall sticky traps painted green. A majority of the adults were captured within 1 m from the ground. About 60% of the adults were males, and 91% of the females were mated. No association was found between numbers caught in the trap and those obtained by sweeping in the trap vicinity. Spittlebug adults were marked with powder Dayglo® and released in pastures. The insects tended to remain within 20 m of the release point, and in some instances as many as 1/3 were recovered 24 hours after the release. Some marked insects traveled as much as 750 m. Very few of the adults released in adjoining pastures of different kinds or between rice or pastures moved from one field to another. Spittlebugs flew at a velocity of 11 km/hour. In a single flight, one adult flew as far as 910 m; thereafter the insect flew higher and disappeared from sight. Flight durations of spittlebugs suspended in laboratory were measured. Based on the flight duration, and flight speed, it was estimated that some spittlebugs could travel up to 3 km.

Index terms: *Zulia entreriana, Deois flavopicta,* Cercopidae, *Brachiaria decumbens,* pasture, dispersal, migration.

OBSERVAÇÕES SOBRE O MOVIMENTO DE ADULTOS DE CIGARRINHAS-DAS-PASTAGENS

RESUMO - Foi observada a altura dos vôos das cigarrinhas, capturando-se os adultos em armadilhas de 3 m de altura, gomadas e pintadas de verde. A maioria dos adultos foram capturados a 1 m do chão. Cerca de 60% dos adultos eram machos, e 91% das fêmeas eram cruzadas. Não foi obtida uma associação entre o número dos capturados nas armadilhas e o dos capturados pela rede entomológica perto da armadilha. Os adultos das cigarrinhas foram marcados com pó Dayglo® e liberados em pastos. Os insetos tenderam a permanecer dentro de 20 m do ponto de liberação, e em algumas ocasiões até 1/3 deles foram recuperados 24 horas após a liberação. Alguns insetos marcados viajaram até 750 m. Poucos dos adultos liberados em diferentes tipos de pastos contíguos, ou entre o pasto e o arroz, atravessaram de um loçal para o outro. As cigarrinhas voaram à velocidade de 11 km/hora. Num só vôo, um adulto percorreu até 910 m; depois o inseto voou a uma altura maior e ficou fora de vista. Foi medida a duração dos vôos suspendendo-se as cigarrinhas no laboratório. Com base na duração do vôo e na velocidade, estimou-se que algumas cigarrinhas poderiam viajar até 3 km.

Termos para indexação: *Zulia entreriana, Deois flavopicta,* Cercopidae, *Brachiaria decumbens,* pastagem, dispersão, migração.

INTRODUCTION

Spittlebugs of the genera *Zulia, Deois,* and *Mahanarva* suck sap and inject toxins into grass plants. This reduces plant growth and in turn the carrying capacity of pastures. By one estimate, the insects reduced green matter content of Brazilian pastures by about 15% (Empresa Brasileira de Pesquisa Agropecuária 1984). Apart from pastures, spittlebugs damage rice and corn (Nilakhe et al. 1984a, Santos et al. 1982). Recently, it was reported that the majority of spittlebugs multiply in pastures and the adults then fly to rice (Nilakhe 1985).

Information about when spittlebug adults move from one crop to another, in what numbers and what causes the insects to move, would greatly aid in developing sound control strategies. Growers often want to know whether spittlebugs from neighbouring fields will invade their fields. Such movements could come from two or more adjoining pastures of the same or different grass species, or could be from a combination of adjoining crops such as rice, corn, sugarcane and pasture. Thus knowledge about short-range movements of spittlebug adults is an essential prerequisite for

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planning successful control strategies – may it be use of fire (Martin 1983), resistant grasses (Cosenza & Naves 1979, Menezes & Moreno 1981, Nilakhe et al. 1985, Reis & Botelho 1980) pasture management tactics (Cosenza & Naves 1979, Naves 1980, Nilakhe 1983), or microbial control (Messias et al. 1983) or a combination of strategies.

We are convinced that short-range movements of spittlebug adults do occur because of the following observations: 1) sudden appearance of a large number of adults in a pasture where none or very few spittlemasses were present, and/or nymphs in earlier stages of development, 2) sudden disappearance of adults from a given site, i.e., as much as a 6 - 7 fold decrease in population in less than 24 hours, and 3) infestations in rice where no spittlebug nymphs are present.

Insect movements may be classified as dispersal and migration. According to Rabb & Stinner (1978), movement that results in noticeable changes in spatial relationships (distances between individuals) is dispersal. Dispersion is in essence a scattering, and results in interspersion when within the breeding habitat and when outside the breeding habitat, migration. Terminology used in describing insect movement is rather vague (Rabb & Stinner 1978) and this fact is well illustrated by Kennedy (1961). Although no information about breeding habitat of spittlebugs is available, we considered that we were studying short-range dispersal of spittlebugs.

To study movement of insects, it is necessary to use some sort of marking technique to identify the released insects. Various techniques have been used, such as paints (Southwood 1978), radioactive isotopes as p32 (Odum & Pontin 1961, Nilakhe et al. 1978) and rubidium (Berry et al. 1972, Steenwyk et al. (1978) fluroscent powders (Sheppard & Wilson 1977), etc.

It is essential that the marking technique used should not be detrimental and should not change behavior of marked insects. For our studies, fluoroscent powder Dayglo® (Dayglo Color Corporation, Cleveland, Ohio, USA) was used to mark a large number of spittlebugs.

Almost nothing is known about movement of Brazilian spittlebugs. Herein it was reported on flight height, distance traveled, velocity, and potential movement of adults within and between pastures, and crops.

MATERIALS AND METHODS

Trap and sweep-net catches to monitor movement

Of the six traps set in pastures of *Brachiaria decumbens* Stapf, three were located at CNPGC, EMBRAPA farm and three near Dourados, MS. At each location traps were placed at least 2 km apart and each trap was encircled with a metal frame covered with fence wire to prevent cattle from damaging the trap. The triangular trap was 3 m tall, 20 cm wide, and held in position by securing it to the metal frame with strings. The trap was painted green and covered with a glue "Verniz Pega Poeira" manufactured by Glasurit Co. São Paulo, Brazil. The trap was painted green because Wilson & Shade (1967) reported that in terms of attractiveness of different colors to the meadow spittlebug *Philaenus spumarius* (L.) the green was intermediate. We did not want to use a color that would either attract or repel spittlebugs. Glue was reapplied to traps every two or three weeks to maintain stickiness. Traps were monitored from November 83 to May 85. Spittlebugs caught in traps were removed about three times a week, separated by species and sexed. Adults appearing in each 50 cm section of the trap were held separately. On the day the adults were collected from the traps, a sweep sample of ten sweeps of a sweep-net was taken in the immediate vicinity of the traps. Sweeping details were the same as described by Nilakhe et al. (1984b). Once the counting and sexing of adults was done, the insects from all the traps were grouped by weeks. When possible, as many as 15 females were removed per group for dissection. The techniques used to separate mated and unmated females were the same as those used by Nilakhe (1976). The spermathecae of the females were examined. In unmated females, the spermatheca is transparent and in mated females it is opaque.

Survival and behavior of marked insects

Adults of the spittlebug (*Zulia entreriana* Berg.) were collected in samples of 15 sweeps of a sweep-net. About 30 - 40 adults were transferred to a 15 cm x 25 cm plastic bag. A pinch of the powder Dayglo® (approximately 70 mg) was added to the bag and the bag was slowly turned upside down 2 - 3 times thus marking the insects. Twenty such marked adults were released in each of the 5 saran covered 1 m^3 cages which were placed in a *B. decumbens* pasture. Similary, 5 cages were infested with unmarked adults. Adult survival was recorded daily, and the cage means were used for statistical analysis.

In Test 2, field-collected nymphs (mostly 5th instar) of *Z. entreriana* were held in cages on grass and the cages were checked daily for adults. The newly emerged adults were considered to be 1-day old; the following day they were marked with the powder and 10 were caged over a potted *B. decumbens* grass plant. Five pots were used each for the marked and unmarked adults. Test 3 was conducted in the same manner as Test 2 except that adults of *Deois flavopicta* (Stal) were used.

Test 4 compared the behavior of marked and unmarked insects. Adults were collected from pastures and marked as described in Test 1. After marking they were held in a 35 cm x 33 cm x 60 cm saran covered cages and were released at the study site immediately. Two hundred and fifty marked and 250 unmarked spittlebug adults (80% *Z. entreriana* + 20% *D. flavopicta*) were released simultaneously each in the center of two pastures of *B. decumbens*. Pasture 1 had an area of 10 ha and the other 25 ha. These pastures were considered to be completely free of spittlebugs. No adults were found in 40 samples of 10 sweeps of a sweep-net, and no nymphs were found in observations at 40 locations in each pasture. During the two subsequent days following the release, all adults present within 2 m radius of the release point were counted. Also adults were collected by sweeping at distances of 5 m, 10 m, 20 m and 50 m from the release point. A rope was tied to a metal pipe driven into the ground at the center of the release point. After reaching a desired distance from the center, for example 50 m, one person walked one complete circle holding the rope. Another person swept for spittlebugs following the footsteps of the person carrying the rope. Roughly 1 sweep was taken for every 1.5 m of the circle. Adults were counted in the field and released. For statistical analysis the counts were transformed as Log (x + 1), where x was equal to the observed count. Data were analyzed as a 3-factor experimental design where the factors were type of adult (marked or unmarked), collection day, and distance from the release point. Tests 1-3 were conducted at CNPGC, EMBRAPA, and Test 4 near Dourados. After completion of these tests, the tests dealing with marked spittlebugs reported in the following sections were undertaken. Laboratory tests were performed at CNPGC, and the field tests near Dourados. The tests were conducted from November to April of 1983-84, and 84-85.

Within pasture movement

Adults were marked, released, and data collected in the same manner as described in Test 4 of the previous section. Only marked insects, usually 500 (± 5% counting error) were released in a *B. decumbens* pasture. Initially, the insects were released at only one point in a pasture; this pattern was repeated 8 times. Later to study the probable adult movement at greater distances, the insects were released at 3 points (different colored powder for each point) in a straight line in such a way that each point was 200 m apart. This pattern was repeated 4 times. In general, the marked insects were composed of about 70% *Z. entreriana* + 30% *D. flavopicta*. Unless otherwise mentioned, the insects were released between 9-10 A.M. or 4-5 P.M.

Further observations on spittlebug movements were recorded with slight modification of the metodology. Two thousand marked insects were released in the center of each of the 3 large *B. decumbens* pastures. Then, during the 2 subsequent days following release, spittlebugs were collected by sweeping along the 4 cardinal directions at 50 m, 500 m and 1000 m form the release point. Ten samples of 10 sweeps were taken at each distance of a cardinal direction.

In 4 tests, spittlebugs were sort of "forced" to fly. Two thousand marked insects were released in the center of each of the 4 ploughed fields free of green plants. The ploughed fields were generally surrounded by pastures, but these pasture were at least 500 m away from the release point. Insects were released at 9-10 A.M. and observations were made by sweeping in the afternoon of the same day and the day after. The general direction of the flight was noted when the spittlebugs were released, and sweeping was done in the respective pastures, 0.6 km, 1.0 km, 1.5 km and 2.0 km from the release point following the flight direction. At each distance, 40, ten sweep samples were taken.

Movement between different kinds of pastures, and between rice field and pastures

In bordering pastures of *B. decumbens* and *Brachiaria humidicola* (Rendle) Schweickt, or *B. decumbens* and *Brachiaria ruziziensis* Germain & Evrard, 200 adults were released along a 10 m line in each pasture using different colored powders. The adults were released 25 m from the dividing line of 2 pastures in such a way that the distance between the 2 release lines was 50 m. In the 2 subsequent days after release, adults captured in 10, ten sweep samples of a sweep-net taken in vicinity of the release areas were examined to see if they had moved from one field to the other. For each of the 2 pasture combinations, the insects were released 4 times. In exactly the same manner, the movement between the bordering rice field and *B. decumbens* pasture was studied. The height of grass plants in the pastures ranged between 20 cm - 35 cm and rice plants were 30 cm - 40 cm tall. The proportion of the spittlebugs released were about 50% *Z. entreriana* and 50% *D. flavopicta*.

Flight height, distance traveled, velocity and flight potential

Flight height and distance traveled were studied by gently tossing an adult into the air. We successfully followed the flight by running after the flying insect. Flight height was estimated, and flight distance was measured by counting the footsteps, from the release point to where the adult disapeared or came to rest on the surface. Flight distance of adults released at different times of a day in a *B. decumbens* pasture, rice field, and in a ploughed field free of any green plants was measured over a 2-day period. Generally, the winds were calm except for the observations of 12-1 P.M. Fields chosen were free of any obstacles (trees, bushes etc.) and a distance from the center of the field to its boundary was about 500 m. Trial flights showed that generally the insects flew in one direction. Thus, releasing adults at a corner of the field provided an observation distance of as much as 1 km.

The flight velocity, distance and duration of individual flights in seconds was measured over ploughed fields. Only those flights were considered valid in which no wind currents were detected. Flight potential was studied in the laboratory by using a method similar to the one developed by Dingle & Arora (1973). A drop of nail polish "Colorama 1010" was placed on the pronotum of an adult spittlebug. Then a thin nylon thread about 10 cm long was glued to the insect by holding one end of the thread in contact with the drop. Thereafter, the insect was suspended in the air and the other end of the thread was inserted in a piece of styrofoam or held in fingers. Time of flights was recorded in seconds and observations ceased when the insect did not fly for 45 minutes. In this manner the spittlebugs, *D. flavopicta* and *Mahanarva fimbriolata* (Stal) of different ages were flight tested. Procedures to obtain spittlebug adults of known ages were the same as given in Test 2 of the section "survival and behavior of marked insects".

RESULTS

Trap and sweep-net catches to monitor movement

The number of adults caught in sweep samples and the sticky traps at 2 of the 6 locations are given in Table 1. The correlation coefficient values of 0.03 for location 1 and 0.01 for location 4 indicated no association between sweep-net and the trap count ($P > 0.05$). Similary, no significant correlation coefficient values were obtained for any of the other 4 locations.

A total of 1289 adults were captured in all the traps. Of this total, 46.9% were *D. flavopicta,* 46.1% *Z. entreriana,* and 7.0% *M. fimbriolata.* The percentages of males and females were 59.6 and 40.4 for *D. flavopicta,* 60,7 and 39.3 for *Z. entreriana,* 60,4 and 39.5 for *M. fimbriolata.* Similar sex ratios were observed even with those insects appearing in 50 cm sections of the traps.

The majority of adults captured in the traps were within 1 m of the soil level irrespective of the spittlebug species (Table 2). In general, the numbers tended to decrease as the distance from the soil increased. Of the 214 females dissected, 91.1% were mated.

Survival and behavior of marked insects

In Test 1, marked field-collected adults of *Z. entreriana* lived the same duration (3.03 ± SE of 0.31 day) as unmarked adults (2.55 ± 0.21) ($P > 0.05$). In Test 2, where the newly emerged adults of *Z. entreriana* were used, the unmarked adults lived 5.9 ± 0.38 days and the marked 6.1 ± 0.40. In Test 3, conducted similary as Test 2, the marked adults of *D. flavopicta* lived 6.6 ± 0.73 days an unmarked 7.4 ± 0.37, days, however, these differences were not significant ($P > 0.05$).

The movement of the marked and unmarked spittlebugs was studied by comparing the numbers captured at various distances after their release (Table 3). The statistical analysis showed significant differences in the numbers captured between different days, and between the numbers obtained at various distances, however, no significant differences were found for numbers of marked and unmarked adults captured ($P > 0.05$). Interactions among the factors, type of adult (marked or unmarked), collection day, and distance from the release point were not significant.

Within pasture movement

The number of adults captured at various distances in 4 of the 8 pastures are given in Table 4. Two pasture with high naturally occurring spittlebugs populations and 2 with low population were chosen as representatives of the 8 pastures. It can be noted that between 7.6% to 30.0% of all the released adults remained within 2 m of the release point, the day following release. In succeeding collections, the numbers decreased gradually. Of all the marked adults captured, 79.7% were located within 2 m of the release point, 15.8% on the 5 m radius circle 3.0% on 10 m, 1.2% on 20 m, 0.3% on 50 m, and 0% on the 100 m radius circle. Considering all the 8 pastures, 50 m was the maximum distance up to which spittlebug movement was detected.

In 4 pastures where the marked adults (marking powder of different color for each point) were released at 3 points 200 m apart, the numbers captured were similar as reported in the preceding paragraph. However, on one occasion, 2 adults were found at a distance of 100 m, and 1 adult of

TABLE 1. Mean number of spittlebug adults obtained by sweeping and the numbers in the sticky trap in the immediate vicinity, 1983-84[1].

Campo Grande-MS, Location 1, 1984			Dourados-MS, Location 4, 1983-84		
Sampling date	Sweep sample mean	No. in sticky trap	Sampling date	Sweep sample mean	No. in sticky trap
19/01	13.5	3	26/11	49.1	235
23/01	4.5	1	28/11	31.2	31
26/01	8.2	2	01/12	62.1	16
30/01	8.9	1	07/12	44.3	29
02/02	6.4	5	09/12	10.7	3
06/02	3.6	0	12/12	3.7	4
09/02	2.2	0	16/12	1.3	0
13/02	1.6	0	19/12	0.7	0
16/02	0.8	0	22/12	7.5	1
20/02	2.2	1	03/01	0.3	0
23/02	0.8	0	11/01	3.4	0
27/02	1.3	0	18/01	11.1	17
01/03	1.8	0	27/01	10.5	12
08/03	5.1	0	01/02	1.2	0
12/03	9.3	0	03/02	0.9	0
15/03	21.5	0	07/02	0.6	0
19/03	23.9	0	13/02	0.1	0
22/03	14.1	0	24/02	0.2	0
26/03	48.8	4	02/03	1.1	0
29/03	23.4	3	03/04	2.4	0
02/04	11.4	0	11/04	2.3	0
05/04	9.6	4	17/04	1.3	0
09/04	15.3	0			
12/04	6.5	4			
16/04	6.0	3			
24/04	4.3	0			
27/04	2.0	0			
03/05	1.4	0			
07/05	0.1	0			
10/05	0.4	0			
17/05	0.4	0			
20/05	0.1	0			

[1] Data from 2 of the 6 locations are presented. A sweep sample mean is based on 10, ten sweep samples of a sweep-net. The wooden trap used was 3 m tall, triangular with each side 20 cm wide, painted green and was covered with a glue "Verniz Pega Poeira". No association was found between numbers caught in sweep sample and the trap in either case.

D. flavopicta was found at an approximate distance of 150 m from the release point. In 2 of the 4 pastures, the same sampling pattern was followed a week from liberation. A total of 13 adults in one pasture and 11 in another were all found within the 10 m radius circles from the release points.

Among the 2000 marked insects released in each of the 3 *B. decumbens* pastures, some were captured at 50 m from the release point, however, none were obtained at 500 m and 1000 m. No marked spittlebug adults were found in 2 of the 4 tests in which adults were released in the center of each of the 4 ploughed fields free of green plants. Sixteen marked adults in Test 3, and 7 in Test 4 were found on the same day of release, and 12 and 6 adults, the day after the release, respectively. All of these spittlebugs were captured at a distance of 0.6 km. On one occasion, 11 of the 2000 marked spittlebugs were found on weeds and grasses along a roadside (this road separated 2 ploughd fields) at a distance of 750 m from the release point and only 10 minutes after their release.

TABLE 2. Percent spittlebug adults captured in 3 m tall sticky traps in *Brachiaria decumbens* pastures.

Trap section from the ground (CM)	Spittlebug species		
	Deois flavopicta	*Zulia entreriana*	*Mahanarva fimbriolata*
0 - 50	58.22	81.54	55.14
51 - 100	20.69	8.69	23.80
101 - 150	8.41	3.98	10.28
151 - 200	6.34	3.61	6.54
201 - 250	3.96	1.76	3.31
251 - 300	2.38	0.42	0.93

Movement between different kinds of pastures, and between rice fields and pastures

The naturally occurring spittlebug densities varied greatly in a study involving movement of the insects between bordering pasture and rice (Table 5). The number of the marked adults recovered during the 2 subsequent days after their release ranged from 1 to 11%. Only 6% of the marked adults (7 of the 114 captured by sweeping) changed their release place (three adults moved from pasture to rice, and 4 from rice to pasture).

The numbers of marked adults captured in the bordering pastures of *B. decumbens* and *B. humidicola*, or *B. decumbens* and *B. ruziziensis* were similar as those reported in the preceding paragraph. The released insects remained in their place of release except that on one occasion, 1 adult released in *B. decumbens* moved to *B. humidicola*.

Flight height, distance traveled, velocity and flight potential

Flights were classified into 2 categories: 1) short distance flights where the spittlebug flew at a height of 2 m or less and generally it was possible to observe the entire flight from a stationary position and 2) long distance flights where the insect flew at a height of about 6 m or higher and generally it was not possible to follow the entire flight from a stationary position. We were aware of the short distance flight, i.e., sort of "hopping" the insects do when disturbed, and thus it was believed that spittlebugs fly very short distances. The second type of flight was discovered accidently one evening about sunset. Many insects were seen flying above a pasture over trees 20 m tall when the winds were calm. Collections using a sweep-net at a height of about 5 m revealed all of the insects to be spittlebugs. The origin of these insects was not known but they were flying from the pasture to the adjoining rice field.

When an insect was tossed gently in the air between 5-6 P.M., it flew to a height of 6 m to 8 m. Then it flew in a straight line, sometimes, going higher. As soon as the spittlebug began flying in a straight line it was kept in sight by running after it. Normally the distance between the insect and the follower was 15 m - 20 m. How the insects chose flight direction was not clear. However, generally the insects flew with the wind. The insects flew in the same direction the wind was blowing even in very low wind velocity (estimated to be 1 km/hour by use of anemometer). On very rare occasions, the insects flew up in the air, made one complete circle of about 2 m radius before flying in one direction. Attempts to follow all flights were not successful. In some cases the insects after flying for some distance moved to higher heights and could not be seen any more (the height was estimated to be 35 m).

Initial observations about insect flights showed apparent differences in flight distance with regards to the time of day and kind of surface where the insects were flight tested. Later, systematic observations were recorded about the flights observed over pasture, rice and ploughed field (free of green vegetation) at different times of a day (Table 6). It was not possible to follow the flights till landing in 82 of the 248 cases. In these 82 flights, after flying for some distance where they were visible, the insects flew at a higher altitude and disappeared from view. Adults of *Z. entreriana* were not as strong fliers as *D. flavo-*

picta; the maximum distance that any *Z. entreriana* adult flew in a single flight was 295 m.

The flight velocity was based on observations of 46 *D. flavopicta* flights. These 46 insects flew 2951 m in 965 seconds. Thus the velocity obtained was 3.05 m/second, or 11 km/hour.

Spittlebug flight potential was studied by suspending the insects in air and recording the flight time (Table 7). Once the insect was suspended we had expected that only one long continuous flight would occur, however, this did not happen. The number of times *D. flavopicta* adults took flight (wing beating of 1 second minimum) was 30 ± 4.0, and for *M. fimbriolata* it was 68 ± 10.8. The insects stopped flying on an average after about 2 hours. Although the insect did not show its flight capability in only one flight, the data still can be used to compare flight potential of spittlebug adults of different ages and different species. Comparison of flight duration of *D. flavopicta* adults showed no significant differences between sexes, and between insects 2 day old versus insects 4-6 day old; interaction of adult age x sex was also not significant ($P > 0.05$). Four to six day old adults of *D. flavopicta* flew significantly longer (362 seconds) than those of the same age *M. fimbriolata* (204 seconds) ($P < 0.05$), however, no difference between the sexes was found, and also the interaction of age x sex was not significant. The maximum flight time for any *D. flavopicta* adult was 18 min and 17 sec. and for *M. fimbriolata* it was 6 min and 54 sec. One *D. flavopicta* flew continuously for 7 min and 50 sec.

DISCUSSION

In the present study, the vertical distribution of spittlebug adults in the 3 m tall trap showed that about 83% were caught in the first 1 m of the trap near the ground. This finding was similar to that of Weaver & King (1954). These authors examined the flights of the spittlebug, *Philaenus leucophthalmus* (L.) by trapping them on tanglefoot bands placed at various heights on a 6 m tall pole in a hay field. Eighty-five percent of all the adults were trapped in the 1.2 m height from the soil. Using a different methodology, about 2 times greater numbers of the spittlebug, *Prosapia bicincta* (Say) were caught in black light traps 15 cm from the soil level than those at 180 cm (Beck & Skinner 1972).

TABLE 3. Number of spittlebug adults found at various distances after release of 250 marked and 250 unmarked adults in *Brachiaria decumbens* pastures free of spittlebugs.

Distance from release point (m)[1]	Number of adults collected the day after release			
	1		2	
	Marked	Unmarked	Marked	Unmarked
	Pasture 1			
2	38	32	22	18
5	17	14	6	3
10	9	4	1	0
20	5	2	2	3
50	0	0	0	1
	Pasture 2			
2	42	36	18	13
5	18	8	0	2
10	2	4	5	4
20	0	1	0	0
50	0	0	0	0

[1] Spittlebugs present within a circle of 2 m radius from the release point were counted. For other distances, the insects were collected by sweeping along the circle of relevant radius from the release point.

TABLE 4. Number of spittlebug adults found at various distances after release of 500 marked adults in pastures of *Brachiaria decumbens*.

Distance from release point (m)[1]	Number of adults collected the day after release					
	1		2		3	
	Marked	Unmarked[2]	Marked	Unmarked	Marked	Unmarked
			Pasture 1			
2	150	-	41	-	2	-
5	9	55	13	68	4	38
10	4	91	2	59	0	57
20	1	121	1	150	0	88
50	0	312	0	270	0	150
100	0	719	0	470	0	265
			Pasture 2			
2	38	-	11	-	4	-
5	13	66	5	61	7	61
10	5	55	2	41	1	59
20	3	64	1	55	0	90
50	0	332	1	191	0	261
100	0	238	0	172	0	205
			Pasture 3			
2	141	-	38	-	6	-
5	21	3	10	1	6	2
10	1	4	0	2	1	4
20	0	19	0	2	1	7
50	0	18	0	11	0	17
100	0	37	0	19	0	23
			Pasture 4			
2	42	-	36	-	17	-
5	12	10	1	14	3	5
10	3	13	0	11	0	7
20	1	19	0	9	0	13
50	0	21	1	18	0	8
100	0	65	0	29	0	31

[1] Spittlebugs present within a circle of 2 m radius from the release point were counted. For other distances, the insects were collected by sweeping along circle of the relevant radius from the release point.

[2] Unmarked indicates naturally occurring spittlebug.

The sexual proportion of *P. bicincta* adults caught in black light traps set at 15 cm from the ground was roughly 85 ♂:15 ♀ (Beck & Skinner 1972). In another study with the same species, the sexual proportion of adults caught in black light traps was 94 ♂:6 ♀ (Byers 1965). In the present study the sexual proportion of adults caught was 60 ♂ :40 ♀. It is likely that males are attracted more to the black light trap than females. In our traps we did not use any light source. Our objective was not to attract the insects to traps but to monitor the natural movement.

No association was found between the numbers caught in traps and those captured by sweeping in the immediate trap vicinity. Thus, the trap (painted green) used in the present study can not be used for accurate monitoring of spittlebug densities. For such an objective, the trap efficiency could be improved by painting the traps yellow, since this color is attractive to spittlebugs (Wilson & Shade 1967), or one may use black light traps (Beck & Skinner 1972, Botelho et al. 1976, Byers 1965). Studies are needed to verify if the black light trap could accurately monitor fluctuating populations.

The majority of females appearing in the traps were mated (91.1%) thus mated females apparently are quite active. Beck & Skinner (1972) did not examine spermathecae of *P. bicincta* females caught in the light traps. However, based on the small number of eggs found in many females, they indicated that young, possibly unmated females were the more active females.

Marking of spittlebug adults with flourscent powder Dayglo® did not reduce their survival in comparison with the unmarked insects. We wanted to compare the movement of marked and unmarked adults in pastures that were completely free of spittlebugs. We finally located 2 pastures that did not have any spittlebugs, and studies conducted in these pastures indicated that movement of marked spittlebugs was the same as the unmarked. Clearly, in studies like these it would not be possible to detect any emigration. Comparison of single flights of marked and unmarked adults of *D. flavopicta* showed that both types of adults flew the same distance. A tendency was observed for a large number of marked and unmarked insects to stay close to the release point. However, no marked adults remained close to the release point when they were released in fields free of green plants. Also, on several occasions mating among the marked and/or unmarked insects was observed under field conditions – another indication that marking apparently did not modify behavior. Thus, the Dayglo® powder may be used in future studies involving spittlebug movement. During the short observation period used in the present study (less than a week) it was possible to visually separate the marked and unmarked insects, therefore an ultraviolet lamp was not required to detect the marked insects as was used by Hogsette & Ruff (1985) to detect the stable flies marked with Dayglo®.

In general, spittlebugs are considered as sluggish insects and weak fliers (Ahmed & Davidson 1950, Byers 1965, Weaver & King 1954). Pass & Reed

TABLE 5. Movement of spittlebug adults between bordering *Brachiaria decumbens* pasture and rice field after release of 200 marked insects in each[1].

Day after release of marked adults	No. of adults obtained in 100 sweeps of a sweep-net				No. of marked adults that moved from pasture to rice (P), and rice to pasture (R)
	Rice		Pasture		
	Marked	Unmarked	Marked	Unmarked	
			Location 1		
1	8	52	12	80	1 (P)
2	3	76	3	146	1 (P)
			Location 2		
1	3	21	4	163	0
2	2	43	2	492	1 (P), 1 (R)
			Location 3		
1	22	39	15	282	3 (R)
2	5	24	5	213	0
			Location 4		
1	3	12	13	136	0
2	4	5	10	77	0

[1] Insects were marked with fluorescent powder of different colors and released along a 10 m line, 25 m from the dividing border of pasture and rice in such a way that the distance between the 2 release lines was 50 m. Sweeping was done in areas close to the release lines. Unmarked insects refer to the naturally occurring spittlebug populations.

TABLE 6. Single flight distances of spittlebug *Deois flavopicta* in m ± SE, at different times of a day and over different types of surfaces[1].

Flight over	Insect observed throughout flight till landing	Distance after which insect flew higher and disappeared from sight
	7 - 8 A.M.	
Ploughed field	62.2 ± 12.5 (9)	75.8 ± 24.6 (6)
Rice	13.8 ± 1.8 (21)	24.2 ± 6.8 (17)
Pasture	14.2 ± 1.4 (36)	33.8 ± 10.9 (4)
	12 - 1 P.M.	
Ploughed field	101.0 ± 60.2 (3)	66.3 ± 12.4 (23)
Rice	13.5 ± 1.3 (21)	(0)
Pasture	25.3 ± 3.8 (28)	45.0 ± 11.4 (12)
	5 - 6 P.M.	
Ploughed field	222.0 ± 95.1 (15)	309.5 ± 67.9 (10)
Rice	31.1 ± 6.2 (16)	120.9 ± 38.6 (6)
Pasture	41.0 ± 11.7 (17)	115.3 ± 62.4 (4)

[1] An adult was held in fingers and tossed gently in air. Once the insect took flight, it was followed by running after it. The number of parenthesis indicate the number of flights falling in each of the 2 categories out of the total flights observed. The height at which insect became invisible was estimated to be 35 m. The ploughed field was free of green plants and the pasture used was of species, *Brachiaria decumbens.*

TABLE 7. Mean flight durations (seconds ± SE) of *Deois flavopicta* and *Mahanarva fimbriolata* spittlebugs when insects were suspended in air by gluing pronotum to a nylon thread[1].

Sex	*D. flavopicta*		*M. fimbriolata*
	2 day old	4-6 day old	4-6 day old
Male	583 ± 47	327 ± 22	152 ± 50
Female	427 ± 49	398 ± 37	257 ± 61

[1] Mean based on 8 insects. Observations were terminated when insect did not fly for 45 minutes.

(1965) reported that most flights of *P. bicincta* were short and occurred when the insects were disturbed. Only on 2 occasions were spittlebug observed to fly in excess of 31 m on a single flight. In the case of the spittlebug, *P. leucophthalmus* (L.), Weaver & King (1954) observed these insects occasionly traveling more than 31 m in a single flight. They also reported that the marked insects traveled as much as 92 m from a release point in 24 hours. In the present study, one adult of *D. flavopicta* flew as far as 910 m (after this distance it disapperead), and several marked adults of *D. flavopicta* and *Z. entreriana* were captured 750 m from the release point. Thus, it was demonstrated that these 2 spittlebug species are not as weak fliers as we had thought initially. We used a sweep-net to monitor the spittlebug movements. Suction machines like D-Vac, traps painted yellow and/or black light traps could be used also for these kind of observations. Since some spittlebugs flew at higher altitudes, they may be trapped using an airplane (Glick & Noble 1961).

Weaver & King (1954) trapped adults of *P. leucophthalmus* on 4 sides of a pole. The percent of the time the wind blew from the 4 cardinal points was also determined. They showed a good association between number of insects trapped and the amount of time the wind blew from a certain direction. They concluded that direction of movement is determined largely, by wind. Our observations also showed that in general spittlebug movement is directed by wind. However, we have observed some spittlebugs fly in absence of wind, and in this case the direction of movement is decided by the insects. Observing spittlebug movements in heavily infested pastures near sundown may give some clues to the direction of movement and the numbers flying.

Rough estimates about flight potential of spittlebugs are indicated by means of an example. In the laboratory one *D. flavopicta* adult flew as much as 18 min and 17 sec. If this insect had flown in a field for this duration, it would have traveled 3.35 km (calculation based on flight speed of 11 km/hour). On an average, adults of *D. flavopicta* could be expected to fly about 1.3 km (average flight duration of 7 min and 14 sec). When aided by wind, they may be expected to travel much longer distances. Some insect species are known to fly very long distances, especially when aided by wind currents (Johnson 1969). Additional studies are needed to determine the role of wind currents in relation to spittlebug flights.

Apart from pastures, spittlebugs damage rice and corn. Generally, spittlebugs multiply in pastures and then the adults invade rice (Nilakhe 1985). Therefore, one tactic for reducing or eliminating spittlebug infestations in rice would be to plant non-graminaceous crops such as cotton or soybean between pastures and rice, or even between pastures and corn. However, the data presented here on spittlebug flight capability indicats that such practices would probably be impracticable. We also swept pastures and the bordering soybean fields (plants about to flower) that were free of grass weeds. Surprisingly enough, some spittlebugs were found in soybeans – one percent of the population densities found in the adjoining pastures. Sampling in some of these soybean fields was done as much as 100 m away from the pastures. It is likely that these spittlebugs were using soybean fields as a "resting station" in their travel elsewhere. Nevertheless, spittlebug adults caged over soybean plants in the field survived an average of 2 days. This is quite impressive considering that simultaneously caged adults on *B. decumbens* plants lived for an average of 4 days. Furthermore, without food source, the caged spittlebug adults survival for only a few hours. Thus, those spittlebugs found in soybean fields bordering pastures were probably using soybean plants for feeding as well. We also swept over soil in a field that was prepared for planting, and was free of any green plants for a period of about 2 weeks. Twelve samples of 20 sweeps of a sweep-net were taken some 300 m away from the adjoining pasture. This sweeping yielded 10 live adults of *D. flavopicta* and 3 of *Z. entreriana*. These spittlebugs had probably landed by accident while flying over the field.

The marked released adults tended to remain in the close vicinity of the release point. Some of the adults released simultaneously in different kinds of pastures, or between pasture and rice, definitely did move, however, their numbers were too few to reveal any major movements. Additional experiments are needed to determine when and in what numbers the spittlebugs will move from one pasture to another.

CONCLUSIONS

1. Of all the spittlebug adults trapped on sticky traps in pastures, the most were found within 1 meter from the ground.

2. More males were found in traps than females.

3. The number of spittlebugs obtained in a trap did not correlate with the number obtained by sweeping in the close vicinity.

4. Marked spittlebugs were recovered at a distance of as much as 750 meters.

5. The maximum distance any adult flew in a single flight was at least 910 meters.

6. Of all the marked adults released in a pasture, only 6% moved to the adjoining rice field and vice versa.

7. The insects flew at a velocity of 11 km/hour.

8. In laboratory, one suspended adult flew for a duration of as much as 18 min and 17 sec.

9. It was estimated that some spittlebugs could travel as much as 3 km, and with aid of wind currents the bugs could fly even greater distances.

10. Based on the spittlebug flight capability, it appeared that the use of a tactic to plant non--graminaceous crops to reduce or to eliminate the bugs infestations between pastures or between pasture and rice/corn would probably be impracticable.

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