RHIZOGLYPHUS ROBINI CLAPARÈDE (ACARI : ASTIGMATA : ACARIDAE) AS A SOIL MITE

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PEST OF CULTURES AND SOIL MITE : RHIZOGLYPHUS ROBINI SEASONAL ACTIVITY

ABSTRACT : *Rhizoglyphus robini* Claparède (Acari : Astigmata : Acaridae) has recently become a pest of onion and garlic in Israel. It often caused heavy damage in fields which had not been cultivated for many years, sometimes following manure applications. Field visits, answers to questionnaires and trapping data were used to follow the phenology of the pest in the soil. Most activity occurred during autumn, the mites becoming inactive as temperatures drop in winter. During spring and summer mites retreat to deeper soil layers, except in irrigated fields. No evidence for diapause was seen, and natural enemies were few and insignificant. Mite-harboring soils were quite variable in their characters. No mites were found in compound bulbs of garlic kept throughout the summer or in manure. When offered natural foods (manure, plant roots, macerated soil animals), *R. robini* thrived on most. It also withstood immersion in distilled water for five weeks and exposure to 6-8° C, and remained fertile. From these data it is postulated that *R. robini* is an indigenous soil mite, an autochthonous species which had become more allochthonous in response to agricultural practices.

PESTE AGRICOLE ET ACARIEN DU SOL : RHIZOGLYPHUS ROBINI ACTIVITÉ SAISONNIÈRE

RÉSUMÉ : Récemment, *Rhizoglyphus robini* Claparède (Acari : Astigmata : Acaridae) est devenu une peste de l'oignon et de l'ail en Israël. Il a souvent causé de gros dommages aux champs qui n'avaient pas été cultivés pendant de nombreuses années, quelquefois à la suite des applications de fumier. La visite des champs, les questionnaires et leurs réponses et les résultats des piégeages ont été employés pour suivre la phénologie de cette espèce dans le sol. L'activité majeure s'est produite en automne, en hiver les acariens devenant inactifs au fur et à mesure que tombe la température. Au printemps et en été les acariens se sont retirés dans les couches du sol plus profondes, excepté dans les champs irrigués. On a vu aucune marque de diapause, et les ennemis naturels ont été peu nombreux et insignifiants. Les sols qui hébergeaient des acariens avaient des caractères tout à fait variables. Aucun acarien n'a été trouvé dans les bulbes d'oignons conservés tout l'été ou jetés au fumier. Quand on lui proposait des nourritures naturelles (fumier, racines de plantes, animaux du sol macérés), *R. robini* la plupart du temps continuait à prospérer. Il a aussi supporté cinq semaines d'immersion dans l'eau distillée et d'exposition à 6-8° C, et il est demeuré fertile.

Sur ces données il est postulé que *R. robini* est un acarien indigène du sol, une espèce autochtone devenue allochtone en réponse aux pratiques agricoles.

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INTRODUCTION

Bulb mites, *Rhizoglyphus* (Astigmata : Acaridae) are cosmopolitan pests of many crops. They infest winter grain, onion and garlic in the field (GERSON, YATHOM and KATAN, 1981 ; RAWLINS, 1955 ; SOMERMAA, 1972), as well as bulbs, corms and tubers in storage (ASCERNO, PFLEGER and WILKINS, 1981 : GARMAN, 1937 ; MULLER and HOLLINGER, 1980). The mites also disseminate bacteria and fungi which infect bulbs, facilitating the pathogens' entry into host plants (POE, NOBLE and STALL, 1979).

Rhizoglyphus robini Claparède has recently become a pest of onion and garlic in Israel. Its life history was studied under controlled conditions and life tables were computed from the resultant data (GERSON, CAPUA and THORENS, 1983), and the possibility of controlling the pest by solar heating of the sun was demonstrated (GERSON *et al.*, 1981). However, very little was known about the phenology of this mite in Israel, except that it becomes a pest mainly in early winter. Nor has much been published concerning the effects of natural diets and some adverse conditions on mite populations in the soil. The lack of such information became important when it was observed that severe pest outbreaks often occurred in fields which had not been cultivated for many years. Furthermore, growers reported some relationship between recent manure applications and mite injury.

This essay is concerned with *R. robini* as a soil mite : phenology, natural enemies, characteristics of soils where this animal lives, effect of natural diets and its survival under harsh conditions. Finally, a hypothesis is presented to account for the recent outbreaks of *R. robini* in Israel.

FIELD STUDIES

■ *Methods.*

The almost total lack of data regarding the field ecology and phenology of *R. robini* in Israel, the extent of its damage, factors relevant to mite occurrence and injury, and control methods implemented, necessitated visits to infested fields. In order to standardize the information obtained, a questionnaire was sent to growers and extention personnel. It included questions concerning extent of damage and dates when injury became apparent, horticultural and plant protection procedures and past field history. Forty questionnaires were duly returned from different parts of the country. Soil samples were obtained during visits and analysed. Predators were collected whenever encountered, mounted, or reared, and sent to specialists for determinations. Live mites and infested plants were regularly brought to the laboratory and examined.

Being soil dwellers, *Rhizoglyphus* mites are hard to detect and monitor ; a suitable method was thus needed. The tendency of these mites to leave decaying foods for fresh ones (MICHAEL, 1903) was used to devise a " mite trap ". A plastic tube (length 135 mm, 24 mm diam.) was fitted with a perforated cap at one end while a wide-mesh metal sieve was welded on at the other. Peeled, wounded garlic pieces were put on the sieve, the tube (Figure 1) then being placed in the soil at a standard depth of 5 cm. A colored ribbon was bound around each tube, to mark it in the field. These traps, which provided no data on their area of attraction, still drew enough mites to provide a crude estimate of their presence in the soil. The traps were therefore widely used to monitor mites in various representative infested fields. A minimum of four traps per field was employed, but as many as 24/field were used in some cases. All fields were visited weekly, the traps and their bait then being changed. The exposed garlic was examined in the laboratory ;

presence of one or more *Rhizoglyphus* mites in a trap made it a "positive". The percentages of positives from the total number of traps renewed during each month was then calculated. Mite samples were regularly taken from field-collected material, mounted and examined. All mites conformed to the concept of *Rhizoglyphus robini* as developed by EYNDHOVEN (1968, 1972) and MANSON (1972). The variability of some characters of this mite was recently explored by GERSON & CAPUA (1981).

Aside from phenological data, the traps also supplied information on the effects of control measures and were used to advise growers concerning mite presence in their fields.

Although soil properties are known to affect the fauna, very little has been published about their influence on *Rhizoglyphus*. LUXTON (1981) obtained large numbers of these mites from Danish beech wood soil in which the mull humus fabric had a pH of 6.1-6.9, and the mineral soil, 4.2-7.6. According to MULLER and HOLLINGER (1980), *Rhizoglyphus* prefers soils rich in organic matter.

Samples were taken from 13 infested fields where garlic or onion were the affected crops. Soil cores (100 cm^3) were obtained from several sites in the field, well mixed and analysed. Soil analyses were conducted according to BLACK (1965) and RICHARDS (1954).

■ *Results.*

The information obtained during visits and extracted from the questionnaires indicated that most injury took place during early winter, i.e., November-December. Grower assessment of damage fluctuated between "light" to "total loss" (a heavily-damaged field is shown in Fig. 2). Plants weakened by other factors (drought, weeds, incautious use of herbicides) appeared to suffer more from *Rhizoglyphus*. No close relationship could be seen between preceding crops and present injury levels as heavy damage was recorded from plots which had been left fallow for many years prior to the present affected crops. On the other hand, rather badly-injured fields were seen in the autumn which then recovered, by spring, indicating some mechanisms of plant compensation.

Cow or poultry manure, or pellets made therefrom (see below) had been applied to over half of the infested fields within two years of mite outbreak. In some plots infestation literally followed the manure spreader (Fig. 3). *Rhizoglyphus* was also collected on celery roots and gladiolus corms in the field, but no damage to either was seen. Mites were further found on roots of the composite weed *Silybum marianum* but did not penetrate the live tissue.

All mite stages were found in the field during early winter, and females brought into the laboratory reproduced there freely. The same held for mites collected in the summer. There is thus no indication that *R. robini* undergoes any sort of diapause.

Little has been published on the natural enemies of *Rhizoglyphus* and nothing is known concerning their effect on pest populations. GARMAN (1937) recorded some predaceous mites as well as a predaceous cecidomyiid gall midge (*Lestodiplosis*).

Natural enemies of both groups were likewise found in Israel. The mesostigmatid mite *Protogamasellus* sp. (determined by Prof. M. COSTA, University of Haifa) was seen feeding in large numbers, on *Rhizoglyphus* mites artifically introduced into the soil. The pests were present in such large numbers that the predator could not have had an important effect on their populations.

Heavily-infested garlic cloves, left in the field under open, shaded conditions were seen to be preyed upon by gall midge larvae. These were reared and sent to Mr. K. M. HARRIS (British Museum, Natural History, London), who identified them as *Trisopsis* sp. and *Lestodiplosis* sp. As in both cases *Rhizoglyphus* was exposed in a rather unnatural condition, the significance of these natural enemies remains unknown.

The monitoring traps were initially used in three infested onion fields, only two of which were irrigated. The relatively-high positive values obtained in April (Table 1) in fields a and b probably

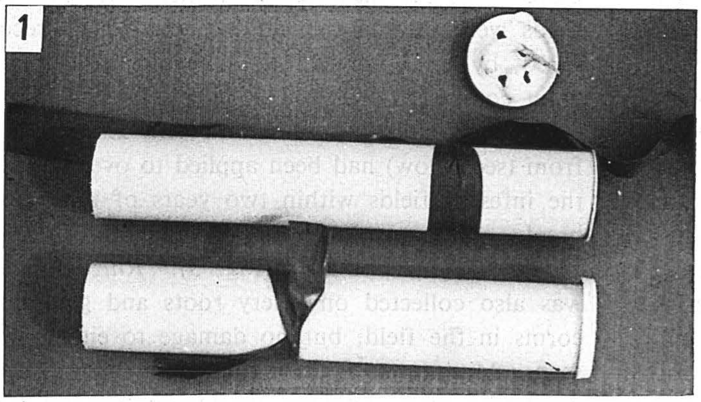

FIG. 1 : Traps used for monitoring *Rhizoglyphus* in the soil.

FIG. 2 : An onion field heavily damaged by *Rhizoglyphus*.

FIG. 3 : An onion plot treated with manure and heavily damaged by *Rhizoglyphus* (foreground), contrasted with another plot which had not received any manure (background).

FIG. 4 : Cow manure after three months' exposure to *Rhizoglyphus*. Note fluffy filter paper, where mites are feeding on manure extract.

FIG. 5 : Cow manure after six month's exposure to *Rhizoglyphus*. Small white dots are mites.

reflected the higher prevailing humidities at that season, brought about by irrigation.

TABLE 1 : Trapping *Rhizoglyphus* in irrigated (a, b) and unirrigated (c) onion fields (TE : total number of examinations ; % P : percent of positives).

	a		b		c	
	TE	% P	TE	% P	TE	% P
February	111	36	131	33	48	33
March	87	23	107	22	96	52
April	116	48	156	42	96	28
May	116	15	156	14	30	3

Traps placed in a field sown to wheat, following a badly mite-damaged onion crop, made it possible to follow mite populations for another season under other conditions. For the sake of comparison traps were also placed in nearby wheat and beet plots with no prior *Rhizoglyphus* history. Mite populations were similarly abundant during February-March (Table 2) with a subsequent spring decline. Mites were thus present in all three plots, although their presence was not manifested by any damage in two of these plots.

Traps were also placed in another wheat field formerly used for irrigated cotton. Yellowing, stunted wheat seedlings in this field were infested by *Rhizoglyphus*. Comparative series of traps

TABLE 2 : Trapping *Rhizoglyphus* in a field (a) previously planted to onion and badly infested by the mite and in wheat (b) and beet (c) fields with no prior mite history (symbols as in Table 1).

	a		b		c	
	TE	% P	TE	% P	TE	% P
December	12	58	—	—	—	—
January	16	50	12	50	6	33
February	16	75	12	33	12	75
March	16	75	12	85	12	58
April	16	25	12	33	12	33
May	14	0	12	0	12	0
June	—	—	3	0	3	0

TABLE 3 : Trapping *Rhizoglyphus* in a wheat field in plots injured (a) and uninjured (b) by mites (symbols as in Table 1).

	a		b	
	TE	% P	TE	% P
January-February	20	45	20	5
March	25	40	25	24
April	20	15	20	20
May	15	0	15	0

were inserted in two adjacent, healthy wheat plots, only one of which was formerly irrigated. No mites were recovered from the drier field. Of the other two plots (Table 3), the injured one had more positives during winter, but not in spring.

It was thus confirmed that *Rhizoglyphus* is a winter pest of onion, garlic and sometimes wheat in Israel, being rare or inactive during summer. Suspicions that peanut pod injuries may be associated with mites presented an opportunity to monitor for *Rhizoglyphus* during the summer growing season in an irrigated field. Traps were placed in an appropriate plot prior to sowing in April. No activity was recorded until late May when a break had to be made for intensive horticultural practices. Trapping was resumed by July and continued throughout September. Trapping during these summer months was done at two depths, 5 and 10 cm.

TABLE 4 : Trapping *Rhizoglyphus* at a depth of 5 cm (a) and 10 cm (b) in an irrigated peanut field (symbols as in Table 1).

	a		b	
	TE	% P	TE	% P
July	24	46	24	83
August	18	22	14	36
September	12	42	12	66

Mites were distinctly more pronounced at the greater depth (Table 4) but occurred at both levels. Irrigation (and possibly the plants' shade on the soil, which would further reduce temperatures and conserve humidity) was thus shown to enable *Rhizoglyphus* to remain active in the soil throughout summer. No visible damage to peanut plots was observed.

Much variability characterised the soils in which *R. robini* had been active (Table 5), probably reflecting the mite's diverse habitats and versatility. It was the only striking result obtained. A few data will be discussed.

Soil texture is determined by the ratios between clay, silt and sand, and affects the water holding and aeration properties of the soil. *Rhizoglyphus* was found in loam to clay soils, but never in sandy ones.

TABLE 5 : Analysis of soils from 13 onion or garlic fields infested by *Rhizoglyphus robini*.

	No. field												
Analysis	1	2	3	4	5	6	7	8	9	10	11	12	13
Texture	Loam	Loam	Loam	Loam Clay	Loam Clay	Loam Clay	Loam Clay	Clay	Clay	Clay	Clay	Clay	Clay
Organic material (%)	1.05	1.24	1.12	1.25	1.12	1.16	0.91	0.97	1.17	0.96	1.13	1.63	1.53
Water in saturated paste (%)	46.1	47.6	44.9	57.1	55.1	57.5	52.8	65.2	64.1	60.4	61.1	68.5	73.5
Conductivity (semens = mmhos/cm)	0.60	0.78	1.10	1.67	1.80	0.80	1.62	2.26	0.71	0.70	0.53	0.92	1.54
pH	8.1	8.1	8.1	8.0	8.0	8.2	8.0	7.9	7.9	8.0	8.0	7.8	7.8
NO (g/g)	40.0	40.0	77.0	69.0	165.	47.0	37.0	137.0	30.0	26.0	24.0	118.0	226.0
P (g/g)	48.5	60.0	55.0	25.0	20.0	30.0	26.5	12.0	31.0	11.0	26.0	26.0	20.0
K (milliequivalent/litre)	0.20	0.25	0.53	0.31	0.27	0.25	0.12	0.25	0.15	0.10	0.19	0.15	0.31
Cl (milliequivalent/litre)	1.0	1.5	3.3	7.4	9.5	1.2	5.0	10.2	3.5	4.2	3.3	4.1	3.2
Calcium carbonate (%)	14.2	16.9	17.3	20.9	22.2	13.3	15.7	19.6	13.1	16.3	12.2	10.6	14.3
Ca + Mg (milliequivalent/litre)	4.6	5.6	7.8	9.8	10.2	6.0	10.8	17.5	5.0	4.6	3.2	6.2	9.4
Na (milliequivalent/litre)	4.5	4.8	6.25	5.9	5.9	4.8	7.5	5.2	2.4	1.9	1.75	2.4	3.7
Salinity Index	3.0	2.9	3.16	2.7	2.6	2.8	3.2	1.8	1.5	1.3	1.4	1.4	1.7
B (g/g)	0.77	0.76	0.81	0.36	0.37	0.56	0.64	0.17	0.69	0.49	0.60	0.59	0.69
Clay (%)	29.5	29.5	28.3	39.0	37.8	39.5	37.8	45.3	52.0	44.5	47.0	47.0	52.0
Silt (%)	35.0	42.5	43.7	41.3	42.5	40.0	35.0	40.0	37.5	37.5	35.0	37.5	35.0
Sand (%)	35.5	28.0	28.0	19.0	19.7	20.5	27.2	14.7	10.5	18.0	18.0	15.5	13.0

Organic material : the values obtained varied between 0.19 and 1.63 %, which are rather low. Bearing in mind that MULLER and HOLLINGER (1980) considered *Rhizoglyphus* to prefer organic soils, these mites appear to thrive under a great variety of soil conditions.

Conductivity : this property is affected by and directly proportional to the concentration of dissolved anions and cations in the soil, as well as being indicative of the osmotic pressure in the soil solution. Both parameters affect the mite by influencing the humidity available to it. They also affect commercial and weed plants, and the soil flora.

Acidity : soils in Israel usually show a basic soil reaction, and all samples varied only between pH 7.8-8.1. This reemphasizes the great versatility of *Rhizoglyphus*, as astigmatic mites are believed to prefer acidic soils (EDWARDS and LOFTY, 1974).

Mineral content : the large variability found here might be explained in the terms used in regard to acidity.

■ *Discussion of field studies.*

The data obtained from visits, questionnaires and trapping allow us to formulate an outline of the phenology of *R. robini* in Israel.

During summer the soil in unirrigated areas is too hot and dry for the mites, which either perish or move to deeper strata. As temperatures drop in autumn and soil cultivation commences for winter crops, mites may return to upper layers. Irrigation, which further reduces soil temperatures may facilitate that movement. The abundant plant material (commercial crops, weeds, fungi) which then grows affords nutrition for the mites. When manure is added, even larger populations occur. Upon planting onion or garlic, a new, apparently very attractive nutrient source is added, as shown by the trapping data. *Rhizoglyphus* feeds on the young, small roots and at the stem plate, causing economic damage. Later, in winter, temperatures apparently drop below the mites' activity threshold, stopping or slowing down their life processes. Plant growth, however, continues, and the onion and garlic plants gain in strength. They are thus less susceptible to renewed mite attack in early spring. The cycle then repeats itself.

In irrigated plots the mite continues its activity throughout summer, feeding on non-commercial plants or not causing injury to commercial ones. It does not appear to be a pest of flower bulbs and corms in the field in Israel.

The occurrence of *R. robini* (sometimes to pestiferous levels) in fields which had remained uncultivated for rather long periods raised the question of the mite's origin. Answers to this query concern not only the case at hand but also the origin and survival of other soil pests under similar conditions. Three possibilities regarding the mite's presence in such soils were explored : 1) That *R. robini* had arrived via infested plant material ; 2) That it came in the manure (Fig. 3), or 3) That the mite is an indigenous soil inhabitant which increased in numbers as conditions became suitable.

LABORATORY STUDIES

■ *Methods.*

Onion is grown from seeds too small and dry for mites. Garlic, however, is grown from cloves which are dry-stored from the preceding year. Samples of compound garlic bulbs were obtained from mite-infested fields and examined throughout the summer. Another possibility, manure, was investigated by running various examples of cow or of poultry manure collected near infested fields through modified Tullgren funnels, or by processing such samples with flotation techniques.

Many diets were offered to the mites in subsequent experiments. For technical reasons these had to be run in two sets : the first with five mite pairs/dish, for 23 days, and the second, with ten pairs/dish, for 50 days. Assessment of results was usually based on the mating frequency method developed by GERSON and THORENS (1982), but at times only qualitative observations were recorded. The diets included :

(1) Peanut extract (seeds soaked in 1.5 their volume in tap water for two days, filtered and diluted to the required concentration).

(2) Poultry and cow manure pellets (Zevel, product of Shaham, Givat Ada, Israel). Their chemical composition (obtained from the producers) is presented in Table 6. Pellets were offered either as wetted solids or as a water extract (50 gr dry/200 ml tap water) soaked onto filter paper (Whatman No. 1).

TABLE 6 : Chemical components (dry weight) of two types of manure pellets.

	Cow manure pellets	Poultry manure pellets
Organic material	57.0 %	65.0 %
N	2.5 %	3.5 %
P_2O_5	2.4 %	2.4 %
K_2O	3.0 %	2.8 %
Ca	2.04 %	2.81 %
Mg	0.77 %	0.88 %
Fe	0.17 %	0.06 %
Zn	125 ppm	358 ppm
Mn	167 ppm	362 ppm
Cu	50 ppm	50 ppm
Water	12.0 %	12.0 %

(3) Garden N : K : P fertilizer (10 gr/100 ml water) (Haifa Chemicals Ltd, Israel), soaked onto filter paper. Other fertilizers (NSO_3, KCl) were similarly prepared and offered.

(4) Fresh cow and poultry manure, collected in the field and presented, either intact or as extracts on filter paper in petri dishes (GERSON and THORENS, 1982).

(5) Soil from an infested field was collected and pressed, the affluent liquid soaked onto filter paper. The same procedure was repeated for soil dug out from under cow and poultry heaps in the field.

(6) Dried oat and vetch hay, and barley straw, were collected in the field, washed and put in padded petri dishes.

(7) Roots of *Silybum marianum* (Compositae) and *Malva sylvestris* (Malvaceae) were obtained

from infested fields, washed and offered as above.

(8) Various soil arthropods (Table 8) were offered freshly macerated in padded petri dishes.

Stress conditions were simulated by exposing mites to two situations they actually face in the soil : prolonged immersion in water, and prolonged exposure to low temperatures. In the former assay, twenty-five mite couples were put in a glass containing 40 ml of distilled water (to reduce any possible elecrolyte effect) which was placed at 22° C. The low temperature experiments were conducted by placing 100 couples of *R. robini* in a glass, as in the former series, but at 6-8° C, in a refrigerator. Samples were removed after two, four and six weeks, checked for survival, and the living were placed on garlic cloves at 22° C.

■ *Results.*

Inspection of oversummering garlic at times revealed dead, shrivelled mites, but no live *Rhizoglyphus* were ever seen among the hundreds of bulbs examined. Nor was this mite found in any cow or poultry manure sample, although a variety of other arthropods were thus obtained. However, when *R. robini* was placed on solid bits of either manure it developed quite well and large populations grew there within two-three months. Feeding was often mainly on the filter paper, which had become impregnated with extract. As the paper began to dry up, the mites aggregated on, in and under the remaining manure. After three months the cow manure started to lose its original shape (Fig. 4), which it totally lost (Fig. 5) another three months later. This mode of comminution probably resembles manure breakdown by mites in the field.

Rather similar results were obtained with the manure pellets. These tended to disintegrate when wetted ; *Rhizoglyphus* then moved in to feed there and below, on the leached extracts. Large (several thousand strong) populations developed on these pellets within a relatively short time. Few mites, however, actually burrowed into the manure or pellets.

Observations of mites on NKP-impregnated filter paper showed little feeding at the beginning. Later the dishes became overgrown by molds on which the mites fed. No trace of the molds remained after three months and the mites had consumed the filter paper, to become quite numerous. Mites placed on hay and straw initially ate molds which had developed there, but later they began to burrow into both. *Rhizoglyphus* populations were on the increase when, after 60 days, the observations had to be terminated.

Mites survived well on fresh or pelletized manure (Table 7) (the larger numbers obtained from poultry manure probably reflected the higher nutrient content of this diet, Table 6). Soil and mineral extracts allowed very little to no reproduction, this experiment on NPK extract producing quite different results from the one described earlier. The difference may be attributed to the presence of molds in the latter experiment. Peanut extract was included only for comparative purposes, and the good association between mating values and number of adults obtained adds credence to the former index.

TABLE 7 : Matings and adults of *Rhizoglyphus robini* obtained after 23 days on extracts of various potential diets.

Extract of	No. matings	No. adults
Peanuts	157	253
Cow manure (fresh)	3	5
Cow manure (pellets)	31	42
Poultry manure (fresh)	86	111
Poultry manure (pellets)	34	46
Soil from infested field	2	3
Soil under cow manure	0	1
Soil under poultry manure	1	4
Fertilizers : NPK	0	0
KCl	0	0
NSO_3	0	0

Most soil arthropods and the two roots afforded enough nutrients to allow *Rhizoglyphus* to survive and to reproduce (Table 8). The unsuitability of ants and Collembola probably reflects on repellent or even unedible chemical components of their bodies. The persistent, albeit modest, development on *Rhizoglyphus* cadavers possibly explains how mites survive on filter paper alone, i.e., they feed on their own dead. Earthworms, certipedes and especially isopods afforded much better nutrients, and so did the two roots.

TABLE 8 : Matings and adults of *Rhizoglyphus robini* obtained after 50 days on macerated invertebrate and root remains.

Diet	No. matings	No. adults
Ants	1	0
Collembola	2	0
Rhizoglyphus	19	5
Gamasine mites	32	7
Earthworms	33	26
Centipedes	52	58
Isopoda	394	723
Malva sylvestris	438	446
Silybum marianum	483	811

To conclude, manures, soil invertebrates and roots quite likely enable *Rhizoglyphus* to survive in the soil and, upon occasion, to produce large populations there.

Some of the mites placed in water immediately sunk while others remained at the water's surface. Ten couples were removed after four weeks and were alive ; the others were taken out a week later. Five mites were dead, the rest almost evenly divided between males and females. Both groups were then subdivided. Some males were placed with virgin females, the others with ovipositing ones. Some females were isolated without males (to see whether, insofar as they had already mated, they would still oviposit), the others with young males. All were kept in padded petri dishes at 22° C and offered garlic cloves.

Some mortality occurred in all groups. Males placed with virgin or older females soon mated and females in both groups soon oviposited dozens of viable eggs. Five of these males lived for four weeks after their water ordeal. Two of the isolated females produced, respectively, 23 and 16 viable eggs ; the others died or did not oviposit. Females placed with young males readily mated and deposited many viable eggs.

It is concluded that a continuous, five-week-long immersion in water would not seriously affect the survival of *Rhizoglyphus* in the soil, and that flooding cannot be considered as a means of control.

Survival rates of mites kept at 6-8° C were 65 % after two weeks, 75 % after four weeks and 71 % at the end of six weeks. Many surviving females from all groups subsequently deposited viable eggs. Winter conditions whice prevail in Israel, where it is seldom as cold as the above temperatures, would thus not seriously affect the survival of *Rhizoglyphus.*

DISCUSSION

Results from the field studies enabled us to outline the field phenology of *R. robini.* Autumn appeared to be the important period of population increase, with a concurrent peak of injury to onion and garlic. This was brought out by answers to the questionnaire which likewise emphasized the mite's pestiferous nature. The field studies also showed that *Rhizoglyphus* may live on the roots of various plants without harming them, that it is attacked by few (and apparently ineffective) natural enemies, and that the mites' numbers might be affected by the presence of manure.

Rhizoglyphus outbreaks in fields which had long remained uncultivated could be attributed neither to mite introductions via infested plant (seed or clove) material nor to its occurrence in the manures. The feeding and survival experiments consequently conducted point to the ability of this species to feed and reproduce on a great variety of diets. Manures are especially noteworthy in this respect, as field damage sometimes followed the spreader (Fig. 3). However, the mite also did well on plant remains and on macerated soil animals. In other words, once established, *R. robini* can survive in the field on many available and sometimes marginal natural foods. To this should be added the pronounced longevity and fecundity of this species (GERSON *et al.*, 1983), its ability to withstand long immersion in water and exposure to cold. The mite also has the capacity of moving down into the soil during hot and dry periods (Table 4) and thrives in many different soils (Table 5 and literature cited above).

Taken in conjunction, these considerations lead us to postulate that *Rhizoglyphus robini* is a true soil- borne invertebrate. It has probably always lived in the soil, subsisting, rather marginally, on dead roots, animal remains, various molds and the like. As fields began to be cultivated, i.e., irrigated and manured, *Rhizoglyphus* reacted rapidly by raising large populations. These mites prefer living plant material to dead and decomposing diets (MICHAEL, 1903) and are rapidly attracted to it. Therefore when onions or garlic were introduced to formerly-uncultivated plots, the mites began to feed onto them, thus becoming pests. This model is rather reminiscent of the one proposed by GERSON and CHET (1981) for r- and K-selected (or allochthonous and autochthonus) soil microorganisms. *R. robini* may thus be visualized as an autochthonus, K-selected species which had existed in the soil in quite low numbers for many generations, living on a wide range of meager diets. In response to recent agricultural practices it shifted along the r-K continuum, becoming more r-selected. Its populations have therefore become more prone to be affected by environmental conditions, i.e., control measures.

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