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INTRODUCTION AND EVALUATION OF *CHILOCORUS BIPUSTULATUS* [*COL. : COCCINELLIDAE*] FOR CONTROL OF *PARLATORIA BLANCHARDI* [*HOM. : DIASPIDIDAE*] IN DATE GROVES OF NIGER

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Chilocorus bipustulatus L. was successfully established in oases of the Aïr Mountain region of Northern Niger (West Africa), where it became the major cause of mortality among adult females of the armored scale *Parlatoria blanchardi* Targioni-Tozzetti. This resulted in significantly lower scale infestation of date palms in a test plot when compared to a control with no introduced ladybeetles. The coccinellids were able to reproduce year-round, but during the hot season were largely confined to natural refuges composed of dense stands of date palms. Dispersal and multiplication occurred primarily during the rainy season, toward the end of which the greatest suppression of scale populations was seen.

Chilocorus bipustulatus L. (fig. 1) is found throughout the Palearctic region preying on a wide variety of coccids, particularly armored scales (**Hodek**, 1973, **Yinon**, 1969), including the white date scale, *Parlatoria blanchardi* Targioni-Tozzetti. The scale has been reported from most date growing regions of the world (**Smirnoff**, 1957) and does not naturally occur together with the beetle except in North Africa and the Middle East (**Gaillot**, 1967 ; **Kehat**, 1967 ; **Martin**, 1972). The extended range of *P. blanchardi* is largely due to man's activities, especially the transport of date palm offshoots for replanting (**Smirnoff**, 1957). Although scale may be inadvertently introduced by this means, predators such as coccinellids would rarely be included. In the case of the Aïr region, the scale may be endemic since it has been observed on the doum palm (*Hyphaene thebaica* Mort.) even in places where dates are not presently grown (**Stansly**, unpubl. data). The small isolated nature of the Aïr region relative to the surrounding Sahara creates an island effect which serves to limit the biota. Perhaps this alone may be sufficient to explain the paucity of natural enemies of the scale and the heavy infestations which occur on date palms as a result, regardless of whether *P. blanchardi* is native or introduced in the Aïr.

In Mauritania 6 species coccinellid had been introduced during the course of a program to control *P. blanchardi* but only *C. bipustulatus* from Iran became established (**Gaillot**, 1967 ; **Laudeho** *et al.*, 1970). This ladybeetle was then introduced with limited success in Niger near the town of Agadez in 1973 (**Kaufmann**, 1977a). The subsequent introduction of *C. bipustulatus* into the oases of the Air region was probably the most successful attempt so far to establish the ladybeetle out of its natural range. The present paper describes the processes of introduction and establishment in the Aïr as well as studies carried out on the ecology of the beetle and its ability to surpress scale populations in this new environment.

In Mauritania and near Agadez, established colonies of the beetle remained small or became extinct due to aestivation and/or poor survival during the hot season (**Iperti** *et al.*, 1970 ; **Kaufmann**, 1977a). However in slightly cooler Aïr the beetles remained active throughout the year, provided groves contained various sizes and densities of date palms. Large crowded trees created shady sites in which beetles collected during the hot season. Thus concentrated, they greatly reduced the number of scales, which were meanwhile allowed to build up in more open stands of smaller trees then relatively devoid of predators. With the return of cooler weather the ladybeetles radiated into these open areas and utilized the large numbers of scales found there.

MATERIALS AND METHODS

Ladybeetles used in this program were descendants of those originally collected from date palms in Iran (**Gaillot**, 1967), cleared through quarantine in France, and subsequently reared in Mauritania for field release there (**Iperti & Brun**, 1969) and at Agadez, Niger (**Kaufmann**, 1977a). In 1974 I collected beetles from trees near Agadez and began introducing them into oases of the Aïr Mountain region, ca 125 km to the northeast. Introductions continued for 2.5 years with beetles either collected from then-established sites or reared in ventilated plastic boxes and fed daily with *P. blanchardi* on date leaflet cuttings. Beetles were introduced, in some cases repeatedly, at 27 sites varying from ca 700 to 1600 m elevation and distributed along the banks of 5 seasonal watercourses within an area of ca 9000 km^2. Most of these sites were less than 5 km apart.

Introductions were made by releasing beetles near the center of groves, usually containing at least 50 palm trees. When available, 50 to 100 adults were placed on scale-infested interior fronds of 3 to 5 trees of medium height (3-5 m). This was done during the cooler hours of the day in hot weather. These sites were returned to periodically to ascertain the colonization of the beetles and level of scale infestation.

To make more detailed studies, a test plot was obtained in April 1974. It was located at Tabelot (ca 800 m elevation, 300 m above Agadez). The plot contained 65 date palms of all sizes on ca 0.3 ha. It was part of a ca 20 ha partially - cultivated strip on the bank of a seasonally dry river containing about 620 date palms of irregular size and distribution, as well as scattered figs, limes, and other trees. Very little insecticide was used by local farmers.Alfalfa and various row crops were planted in and around the study plot and irrigated as required by animal traction. A control plot, located ca 5 km distant and isolated from other introduction sites, consisted of 65 date palms mostly mature. Because the higher water table, they required less irrigation than those on the test plot. No *C. bipustulatus* was found there during the study.

Temperature was recorded daily from a maximum-minimum thermometer placed in the shade at the study site. Rainfall data were gathered by the "Office de Recherche Scientifique et Technique Outre-Mer" (ORSTOM) with pluviometers placed at Tabelot and elsewhere in the zone. Additional data were obtained from the government weather station at Agadez.

Vegetative growth of 2 date palms in both. the control and test sites was measured by placing a pin in the rachis of a frond as close as possible to the terminal bud and measuring its displacement upward a month later.

To determine scale density, leaflet samples were taken twice monthly from the test and control plots. The density of living adult female scales and number of eggs and/or larvae was determined by lifting the shield with the point of a probe in a microscope field of known area. Dead adult females were counted and classed in 4 categories according to cause of death. The 1st category consisted of scales preyed upon by coccinellids, as indicated by a large feeding hole

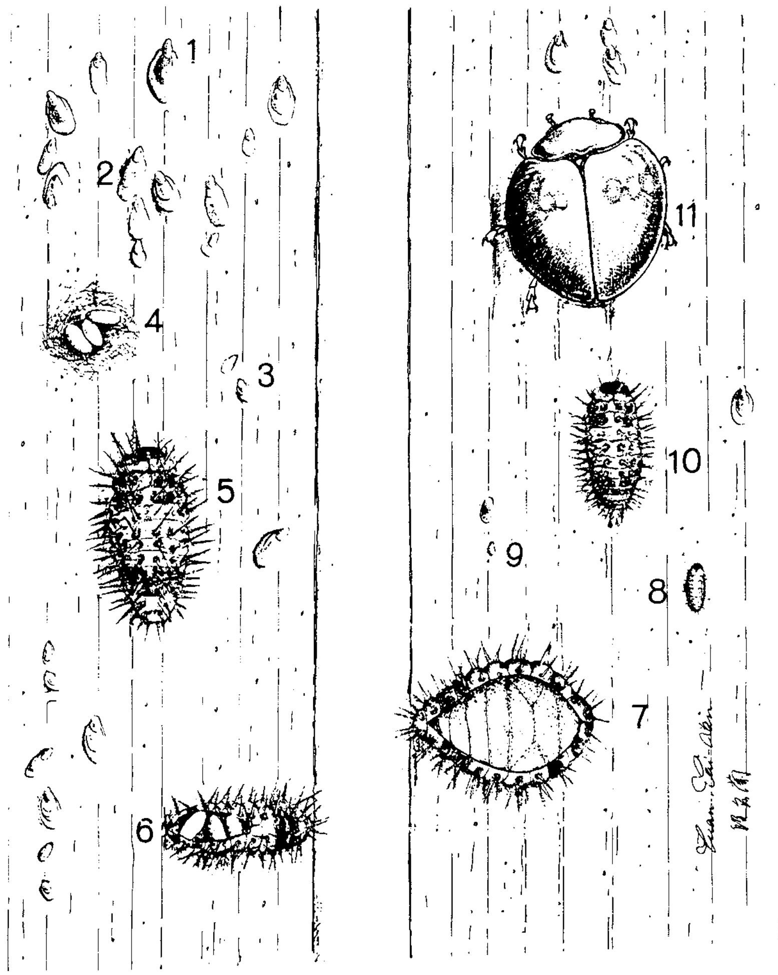

Fig. 1. Stages of *C. bipustulatus* and *P. blanchardi* on the inner surface of a date palm leaflet.

1. Mature female scale.
2. Male scale puparium.
3. Third instar scale.
4. Coccinellid eggs laid in spider web.
5. Fourth instar coccinellid larva.
6. Coccinellid eggs laid inside empty 3rd instar exuvia.
7. Coccinellid pupa attached to midrib.
8. First instar coccinellid larva.
9. Second instar scale.
10. Third instar coccinellid larva.
11. Adult coccinellid.

in the top of the shield. Predation by the mite *Hemisarcoptes* nr. *coccophagus* Meyer (*Acarina : Hemisarcoptidae*) comprised the 2nd category. This was determined either by the presence of the mites themselves, their exuviae, or impressions of the mites left in the deflated scale cadaver (**Kaufmann**, 1977b). The 3rd category consisted of diseased individuals which were dark and liquified except for a whitish, vermiform gut-remnant. Any other dead scales for which the cause of death was unknown, were counted in the 4th category.

Intensity of infestation was monitored on 30 date palms in both the control and study plots by visually ranked estimation on a scale of 0 to 5 according to a method modified from **Laudeho & Bénassy** (1969). A rank of 1 indicated an average of 8 mature ♀♀/cm^2 ; a rank of 2, 15/cm^2 ; and a rank of 3, 35/cm^2. Higher infestations seen in other groves were ranked the same way but not counted. Ultimately, only infestation of central fronds was used as a criterion of overall severity of attack because this consists of only young scales, whereas old dead scales accumulate on outer fronds, biasing the estimate upward.

Five date palms 2.5-4.0 m in height were selected at the study plot on which all stages of *C. bipustulatus* were counted every 5 days. Infestation was ranked on a per-frond basis and leaflet samples taken. Adult coccinellids were collected from surrounding trees and dissected to determine reproductive state. Using a stereoscopic microscope, all mature eggs were counted and the ovary measured from the tip of the largest ovariole to the posterior end of the lateral oviduct.

RESULTS AND DISCUSSION

Establishment

Following the 1st small releases in February 1974 (N = 15), coccinellids survived the hot season only at a single site. It is perhaps significant that the site was located on Mt. Bagzan, at an elevation of 1600 m. This large grove sheltered by hills on 3 sides must have been cooler during the hot season than the other sites 700-900 m lower where no beetles became established on the initial round of introductions. However, with repeated effort, *C. bipustulatus* did eventually become established throughout the zone. In October 1978, more than 2 years after the last release, ladybeetles were recovered at all sites visited (N = 25) within a radius of about 95 km from Tabelot. This included areas as much as 15 km from the nearest release site. It is not certain whether the beetles arrived at all sites on their own or with the help of local farmers.

Using the presence of ladybeetles a year or more after their introduction as a criterion of establishment, release of 100 or more ladybeetles (N = 24) was significantly more successful (50 %) than release of fewer (15 %, N = 26 — χ^2 test, P = .02). By the same criterion, the success rate was significantly higher (43 %, N = 31, P = .05) for releases made during the rainy season or shortly afterwards than those made at other times (16 %, N = 19). Thus establishment was most likely after large releases during the rainy season.

Weather

In 1975, 62.3 mm of rainfall was registered at Tabelot and only 40.6 mm in 1976 (fig. 2). Typically most rain comes in August in the form of a few heavy storms. January was the coolest month with average minimum of 8 °C and 2 nights of frost in low-lying places. May was the hottest month, with average maximum of 37 °C.

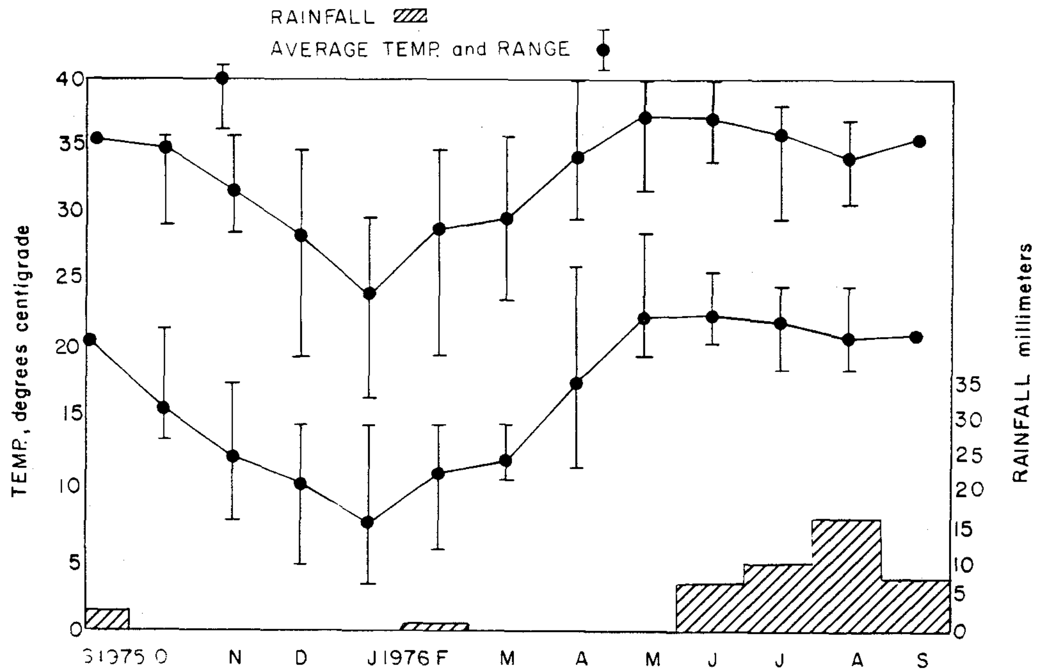

Fig. 2. Meteorological data for study site Sept. 1975-76.

GROWTH OF THE DATE PALM

Growth of fronds was most rapid during the rainy season (90 cm/month), slowest during the cool-dry season (30 cm/month), and intermediate during the hot-dry season (45 cm/month). Water stress on palm trees was probably less severe in the test and control plots than in most surrounding groves which usually lay fallow and unwatered during the hot season. Lack of irrigation at this critical time undoubtedly exacerbated the effect of hot dry weather which caused the ladybeetles to leave all but the most favorable sites.

PHENOLOGY OF *P. BLANCHARDI*

Scale oviposition was lowest in January as indicated by the presence of eggs and/or larvae under the shield (10 %, N = 217), highest in March (75 %, N = 768), then steady at about 63 % through August (N = 10, 641). Egg clutches were largest in March with 30 % of gravid females containing from 2 to 5 eggs. From April through August, only 12.8 % contained more than 1 egg. However, this may have been due to more rapid development of eggs rather than decreased production.

Infestation of the central fronds of 30 date palms in the control plot was lowest during the cool season and rose steadily throughout the hot season (fig. 3). This buildup, most noticeable in open stands, was probably due to the greater inhibitory effect of high temperatures on both tree growth and predators (see below) than upon the scale. Scale infestation dropped again during the rainy season with increased frond growth and predator activity.

PHENOLOGY OF *C. BIPUSTULATUS*

Reproducing *C. bipustulatus* could be found somewhere in this region at any time of the year. However, there were considerable differences between sites and even between trees within sites, depending on the season. At the study plot in Tabelot, populations of coccinelids increased during the rainy season. This was most striking in stands of small or middle-sized trees where the beetles had been relatively inactive during the preceding hot season. With scales plentiful and climatic conditions moderate, the rainy season was the most favorable period for reproduction of *C. bipustulatus.* The coccinellid population was still increasing in the study plot during September as indicated by the fact that larvae outnumbered adults. This trend reversed in October when adults peaked but larvae decreased. By November, adults had also decreased (fig. 4).

Different climatic conditions in other regions cause *C. bipustulatus* to have different phenologies. For example, in Atar Mauritania the rainy season is later and hotter than the Aïr, delaying peak adult populations until December, while in the Middle East where the cool and rainy season coincide in the winter, most adults in an interior oases were seen in May (**Iperti** *et al.* 1970 ; **Kehat**, 1968 ; **Tourneur** *et al.*, 1976).

It was equally clear by dissection of beetles from the study plot that reproduction began declining soon after the rainy season. Whereas 67 % of females were gravid in September (N = 6), only 19 % were so in October (N = 16), and none were gravid in November (N = 28). During this 3 month period, average ovary length decreased from 2.5 mm to 0.9 mm (range 4.0-0.5). In spite of cool temperatures, vitellogenesis began again in December (25 % gravid, average ovary 1.5 mm, range 0.3-3.8, N = 16), and oviposition in mid-January.

The percentage of females in a reproductive state was not correlated with average temperature which fell steadily from September to January ($r^2 = .03$, arcsine transformation). Low reproductivity during October and November was more likely caused by lack of food in the study plot where ladybeetles had consumed most of the scales and then either emigrated or became non-reproductive. Later in the cool season when there were fewer coccinellids to compete for limited resources, significantly more became reproductive ($P < .01$, χ^2 test). In contrast, reproduction was continuous during the cool season in out-lying trees which were colonized too late for food to be exhausted. Movement of *C. bipustulatus* from areas of low scale density to areas of high scale density has been reported by **Rosen & Gerson** (1965), and the correlation of fecundity with prey availability by **Hecht** (1936).

Numerous egg clutches deposited by "overwintering" females were found in February. However, instead of pupating, 5th instars disappeared, as did the remaining old adults. Since infestation was still very low at the time, I assumed that the larvae had starved, although at least a few were taken by predators such as *Chrysopa* sp. So the "spring" generation of coccinellids ended abruptly, again probably from lack of food. Reproduction continued at other sites where scales were more numerous.

During the hot season, activity of *C. bipustulatus* was largely confined to large mature trees, especially those in dense stands. Small isolated trees were abandoned by the beetles. A similar pattern was observed on a small scale in the study plot among the 5 trees monitored there (fig. 5). Tree # 4 was small (ca 2 m) and 8 m fro its nearest neighbour. It was abandoned by *C. bipustulatus* during the hot season and was still not reinhabited by early September. Tree # 1 which was resistant to scale was also abandoned, even though it was larger (ca 3.5 m) and closely surrounded by other palms. In contrast, a small but active colony of *C. bipustulatus* maintained itself on tree # 2 throughout the hot season. This was the largest of the 5 trees (4 m), located closest to the center of the grove, and considerably infested with scale. Thus, protection (proba-

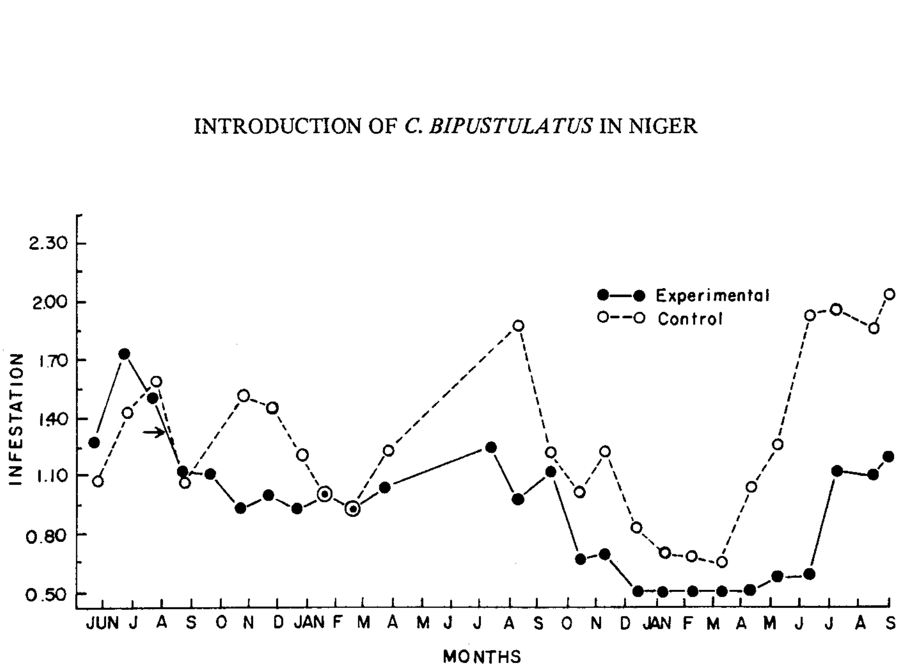

Fig. 3. Infestation of *P. blanchardi* on central fronds of 30 date palms. Arrow indicates introduction of *C. bipustulatus* in test plot.

bly shade) afforded by a large tree surrounded by other trees and adequate scales for food were prerequisites for continued activity during the hot season.

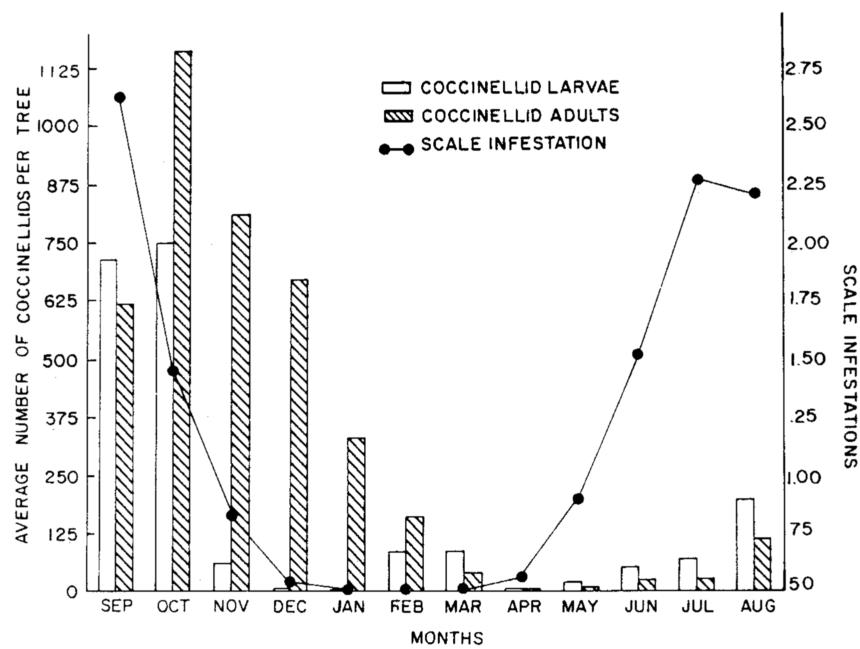

Fig. 4. Seasonal abundance of *C. bipustulatus* and *P. blanchardi* on 5 date palms in the test plot.

EFFECT OF *C. BIPUSTULATUS* ON MORTALITY OF *P. BLANCHARDI*

In the control plot, where *C. bipustulatus* was absent, 40 % of adult female scales (averaged by months) were found dead from February through August 1976 (N = 3561), significantly fewer than in the study plot (P < .001 χ^2 test). There were 36 % dead in February (N = 188), 41 % in May (N = 284), and 31 % in July (N = 1259). In the absence of *C. bipustulatus*, the mite *Hemisarcoptes* sp. was the major mortality factor. It was less effective during hot weather, causing 95 % of total mortality in March (N = 608), 23 % in May (N = 117) and 52 % in August (N = 330). An unidentified "liquifying" disease caused an average of 26 % of mortality from April through August, generally killing the scales before they could fully mature. Other mortality, perhaps caused by larvae of *Cybocephalus* (*Cybocephalidae*), accounted for another 25 %. A small native coccinellid, *Pharaoscymnus numidicus* Pic, which feeds preferentially on immature *P. blanchardi* (**Kehat**, 1968b), caused 2 % of adult mortality.

In plots where *C. bipustulatus* was present, a monthly average of 44 % of adult female scales were found dead (N = 20, 306). This was significantly higher than the control in February, March and April but lower in July and August (χ^2 test). The highest percentage of dead scales was found in February (67 %, N = 1466). Because neither scale nor ladybeetle had been very active for the previous 2 months, 67 % is probably a conservative estimate for the percentage of scales which were dead during the entire cool season. The lowest mortality (22 %, N = 2798) was in July. *Chilocorus bipustulatus* caused 73 % of mortality in February but only 7 % in July. In this relative absence of predation by coccinellids, *Hemisarcoptes* sp., disease, and unidentified factors again predominated, accounting for 9 %, 43 % and 41 % of total mortality, respectively.

It might seem that mites and ladybeetles were mutually exclusive. **Kaufmann** (1977b) thought this occurred because the beetles killed mites while feeding on infested scales. In one case I observed, coccinellids were in much greater numbers on trees without mites than on adjacent trees with the same density of scales, many of which were either being fed upon by mites or already dead. When crowded, the mites form hypopi which have been found under the elytra of *C. bipustulatus* both in the Middle East (**Gerson**, 1967) and Niger (**Stansly**, unpubl. data). Under those conditions, the benefit the mites gain from the coccinellids through phoresy may outweight the harm done by predation.

Throughout a 2 year period following introduction of *C. bipustulatus*, scale infestation in the study plot remained consistently and significantly below that in the initially more infested control plot as measured by ranked estimaes (P < .0001, T test, fig. 3). The 1st year the beetles were present, scale numbers declined steadily until the hot season when there was a slight increase, followed by a rapid decline during the rainy season when the beetles were most active. By April there were still only 3 adult ♀♀/cm^2 on exterior pinnae. Scale density then proceeded to increase 10 fold by August to 30 scales/cm^2 before beginning to decline again with resurgence of ladybeetles. In spite of the absence of ladybeetles in the test plot during the dry season, infestation was only 1/2 that of the control. A peak of activity during and just following the rainy season was a consistent feature of the coccinellid's phenology, and this was apparently sufficient to cause overall decrease of scale throughout the year.

C. bipustulatus will probably remain a self-perpetuating member of the fauna in the Aïr, at least as long as dates continue to be grown. It has significantly reduced scale infestation even though its activity and distribution fluctuated greatly, especially at first. The presence of dense stands of trees tended to stabilize these fluctuations resulting in regular annual or biannual predator-prey cycles and helping to insure against local extinction of the beetles. **Kehat** (1968a) also reported that mature, as opposed to young, groves favor *C. bipustulatus*, and **Kaufmann** (1977a) suggested that small dense stands of date palms should be planted as refuges within the matrix of normally spaced trees. Another beneficial manipulation might be supplemental feeding

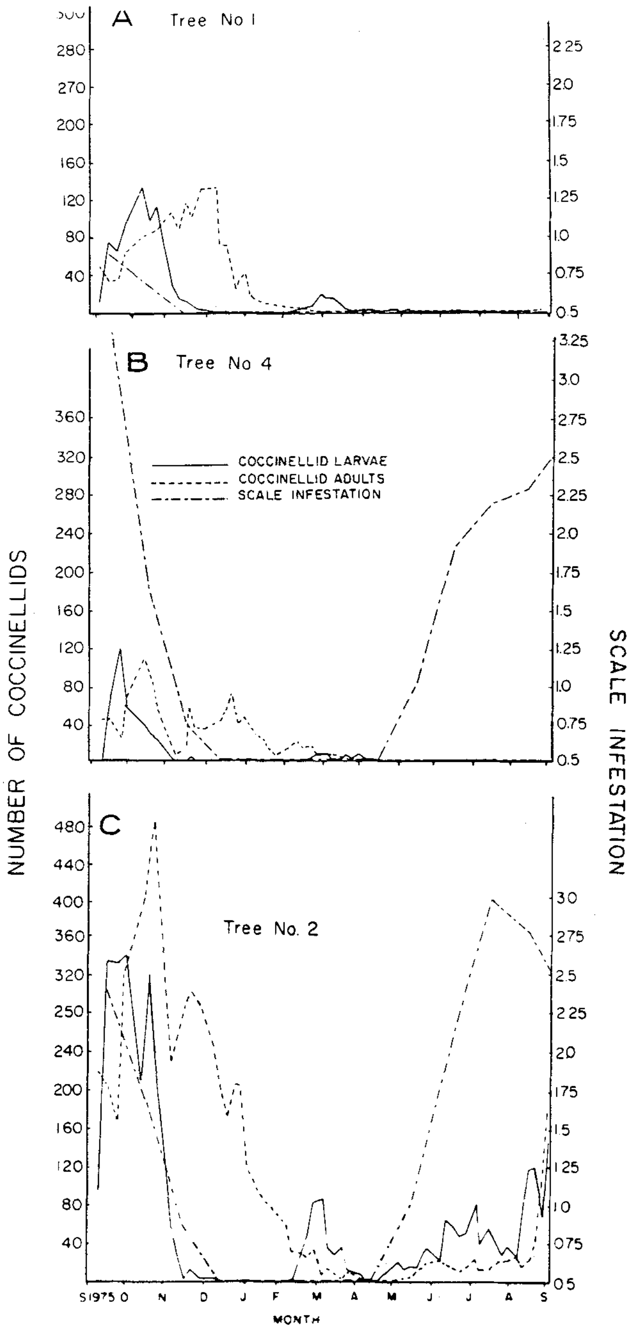

Fig. 5. Seasonal abundance of *C. bipustulatus* and *P. blanchardi* on 3 separate trees in the test plot.

of coccinellids with "food sprays" at selected sites in the spring when both immatures and adults might otherwise starve (**Hagen** *et al.*, 1970 ; **Smith**, 1965 ; **Applebaum** *et al.*, 1971). Control of *P. blanchardi* would probably be further improved by introduction of such hymenopteran parasites as *Archenomus arabius* Ferrière, *Aphytis mytilaspidis* Le Baron, *Aphytis citrinus* Compère, and *Pteroptrix* sp. Westwood (*Aphelinidae*) which are effective in the Middle East (**D. Rosen**, pers. comm.).

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RÉSUMÉ

Introduction et évaluation de *Chilocorus bipustulatus* [*Col. : Coccinellidae*]
pour la lutte contre *Parlatoria blanchardi* [*Hom. : Diaspididae*] dans les palmeraies du Niger

Chilocorus bipustulatus L. a été établi avec succès dans les oasis des montagnes de l'Aïr, au nord du Niger, où il est devenu la cause principale de mortalité des adultes femelles de la cochenille, *Parlatoria blanchardi* Targoni-Tozzetti. Il en résulta un taux d'infestation des dattiers expérimentaux significativement plus bas par rapport au témoin sans coccinelles introduites. Apte à la reproduction toute l'année, la coccinelle se limitait aux touffes denses de dattiers qui constituaient des abris naturels pendant la saison sèche. Elle se dispersait et se multipliait surtout durant la saison pluvieuse, vers la fin de laquelle, on assistait à la plus grande réduction de la population de cochenille.

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