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The distribution of overwintered *Coccinella septempunctata* L. (Col., Coccinellidae) adults in agricultural crops

By A. HONĚK

Abstract

In 1978–1981 the distribution was investigated of adult overwintered population of *Coccinella septempunctata* in main agricultural crops of Central Bohemia (alfalfa and clover, bean, sugar beet, maize, potatoes, spring and winter cereals). The population density was estimated by visual counting along a standard transect. Average decade population densities (from May 1 to June 30) were calculated. These data were transformed to proportion of total adult population of *C. septempunctata* of arable land, present on a given crop at the respecive decade. The most important hosts of adult populations were alfalfa and clover (early May–early June) and spring cereals (from

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Z. ang. Ent. 94 (1982), 311–319

ISSN 0044-2240 / InterCode: ZANEAE

late May). Considerable population density was attained also on sugar beet, bean, and maize, but these crops harboured usually only a small fraction of total adult population due to small area under them. On potatoes and winter cereals the adults were scarce. Relative adult density in different crops varied annually, mainly as a consequence of variation in aphid abundance. The overall population density of *C. septempunctata* adults varied, in years of observation, by 2 magnitudes. It is argued that, in May, adult populations of field crops are founded mostly by immigrants from hibernation sites. Agricultural practices most negatively influencing adult populations were first cutting of alfalfa and clover by chopper harvesters, and chemical treatment of sugar beet against *Aphis fabae*.

1 Introduction

The population density of *C. septempunctata* L. adults in stands of agricultural crops depends largely on environmental conditions, mainly biotic: aphid abundance and plant density (HONĚK 1979). Both these characteristics change with the course of the season. Thus the suitability of different crop stands for *C. septempunctata* adults changes as the plant grow and aphid density increases or decreases. Moreover, agricultural practices may substantially influence coccinellid abundance on some crops. In May and June, 1978–1981 we investigated the population density of overwintered *C. septempunctata* adults on main agricultural crops in central Bohemia. The aim of the work was 1. to determine seasonal and annual changes of population density in various crops, and 2. to estimate the relative importance of various crop stands as reservoirs of coccinellid populations.

2 Material and methods

The population density of adults was regularly recorded in central Bohemia on localities representing the main landscape types of this region: 1. The Elbe-lowland between Český Brod and Kolín; flat agricultural landscape with sparse forests, altitude 200–250 m above sea level. 2. Surroundings of Praha-Ruzyně; hilly agricultural landscape with a mosaic of small forests and urban areas, altitude 300–400 m. 3. Surroundings of Miličín in Středočeská vrchovina Highlands, 70 km S of Praha, a submontane landscape with complexes of larger forests, altitude 600–700 m. Supplementary counts were made also in other localities.

The population density of overwintered beetles was recorded in May and June. The observations were summarized in decades (I–VI) starting from May 1 (the 3rd "decade", May 21–31, had 11 days). We investigated the stands of 7 main crops: forage leguminosae, alfalfa and clover (further FL, which cover 12.4 % of arable land in Central Bohemian Region, a political district around Praha with about 60–70 km diameter), bean (B, 0.8 %), sugar beet (SB, 7.6 %), maize (M, 10.6 %), potato (P, 3.3 %), spring cereals, chiefly barley (CS, 25.0 %), and winter cereals, chiefly wheat (CW, 27.9 %). These data of 1976 did not change by more than 1 % in the next years of observation. The rest of arable land in Central Bohemian Region (12.4 %) is covered by various stands (the largest fraction by non-perennial meadows and rape), with *C. septempunctata* adults almost absent in the years of observation. We made 2–15 observations on every crop in each decade.

The population density of beetles was recorded by visual counting over a transect of a given length. For estimation of population density (observation) we repeated the counting in 93 m (100 walks) transect, 3–5 times. The observations were made during the cold but sunny forenoon hours. *C. septempunctata* imagines like to bask in incident sunshine. The observer should proceed having the sun in his back and inspecting the stand in direction of incident sunrays. The width of the belt in which coccinellids are counted (about 1.9 m in our case) is determined by observer's height. Thus all *C. septempunctata* adults, both sitting on plants and on insolated soil surface, may be counted. The efficiency of the method depends largely on microhabitat temperature. The periods favourable for counting are long in cold days, but restricted to early morning in warm days (fig. 1). The efficiency of counting is nearly 100 % of instant population if the temperatures within stand are below approx. 25 °C and only the insolated portions of plants and soil surface are warmer. When the temperature rises also in shaded strata of the stand, the activity of adults increases, they disappear from visible places, so that only about 25–30 % of them are visible during the warm part of the day. We restricted our observations to appropriate cool parts of day.

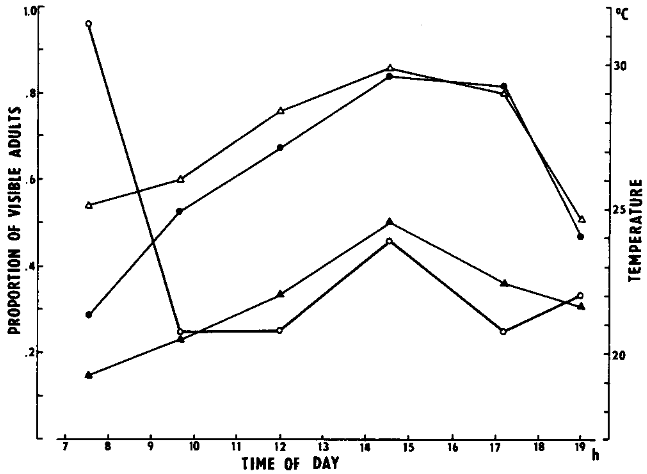

Fig. 1. The effect of temperature on the efficiency of visual counting of *C. septempunctata* adults. Alfalfa, June 2, 1981. ○——○ proportion of visible adults; absolute density (= 1.0) was determined by hand sampling of adults at 25 m^2; △——△ temperature of upper insolated leaves; ●——● temperature of shaded leaves within the plant stand; ▲——▲ temperature of shaded soil surface within the stand

Separately for every decad we estimated, what part of total *C. septempunctata* population of central Bohemian arable land is present in stands of particular crops. We used the formula $P_i = D_i \times A_i / \Sigma D_i \times A_i$, where P_i is the proportion of total *C. septempunctata* population of arable land present on i-th crop, D_i is the relative adult density on the i-th crop (density at the most occuppied crop in a given decade is 1), and A_i is the proportion of arable land occupied by i-th crop (see figures above). In our calculations we took into account the dramatic reduction of coccinellid densities by first harvest of FL (decades III–IV) and counted with respective densities and proportions of harvested and non-harvested FL area. Being inferred from relative numbers, our calculations are appropriate for within decad comparisons of coccinellid distribution, but do not reflect changes, in successive decads, in total *C. septempunctata* population of arable land, as influenced by immigration from hibernating quarters (in May), and dying out (in June).

3 Results

3.1 Density in different crops

The change of population density of *C. septempunctata* in different crops had specific patterns which were similar in years of observation (fig. 2).

In spring, agricultural crops are populated mainly by imagines immigrating from hibernation sites at non-agricultural land (forest edges, hills). Only a negligible fraction of population can overwinter within stands of permanent crops. The beetles appeared first in FL. The migration begun usually at mid-April; thus at the 1st decade of may the adults were already present at high concentration, which only slightly increased afterwards. In exceptionally cold spring 1979 massive immigration was shifted to mid-May.

In fields of bean and sugar beet, the adults appeared immediately after the settling of aphids (*Aphis fabae*, and *Acyrthosiphon pisum* in bean) which occurred between May 15–25. The coccinellids became most abundant in first two decades after aphid settling. In 1979 they were present by about 14 days earlier on bean than in sugar beet fields, being attracted by *A. pisum* which

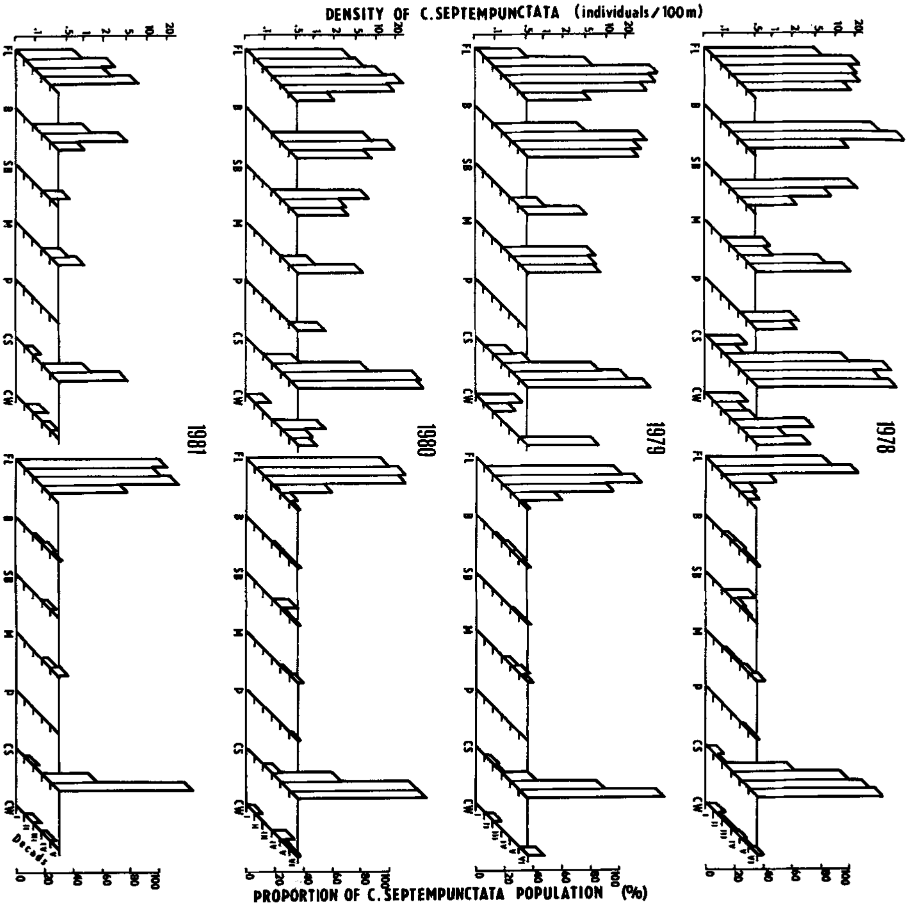

Fig. 2. Density of *C. septempunctata* adults (no. of individuals per 100 m transect, *left*), and proportion of total adult population of arable land present in main crops of central Bohemia *(right)*. FL – forage leguminosae, B – bean, SB – sugar beet, M – maize, P – potatoes, CS – spring cereals, CW – winter cereals. Counting not performed in decade VI, 1981, and distribution of populations not calculated in decade I, 1979, due to low population density of coccinellids

migrated earlier than *A. fabae*. The mean population density of *C. septempunctata* was always rather higher on bean than in sugar beet. This was partly due to destruction by chemical treatments of dense aphid and coccinellid populations in the latter crop.

Maize usually was not colonized earlier than in early June, due to late sowing dates. The density of *C. septempunctata* was usually lower here than in above crops. At this time, the sparse stands of young maize plants with sparse aphid populations (in decades III–V) were more convenient for *C. quinquepunctata* adults (HONĚK 1982).

Potatoes had in all years of observation very low coccinellid population density. Although in Bohemia the potatoes are suitable hosts of several aphid species, the aphid density in May–June was next to zero, as the peak of aphid infestation came later in the season. Thus potatoes, grown mostly in submontane regions, became suitable hosts of coccinellid populations from late June onwards (SKUHRAVÝ and NOVÁK 1957).

Cereals appeared most important hosts of coccinellid populations in all years of observation. There existed, however, a large difference between dense (mostly winter) and sparse (mostly spring) stands, due to the negative effect of increasing plant density on *C. septempunctata* abundance (HONĚK 1979). At first, small quantities of *C. septempunctata* adults appeared on winter rye. They were attracted by aphid *(Sitobion avenae)* populations occurring there at the time, when scarce in other crops (with exception of FL). These aphids probably overwintered within rye stands. Most rye in central Bohemia was harvested as forage around mid-May. Later on, *C. septempunctata* adults were much scarcer on winter cereals (wheat) than on spring ones. The coccinellid populations of winter cereals remained low even when aphid populations grew after the settling of new migrants in late May. Of course, this was true only for well, evenly developed stands of winter cereals. On poor stands or along the field margins coccinellids attained fairly high density. Such places were relatively small in comparsion with the total area of winter cereal stands, and consequently the average coccinellid density was not substantially influenced. By contrast, the density of spring cereals at the time of aphid immigration (early in decade III) was largely acceptable for *C. septempunctata.* Only randomly settled individuals appeared before aphid alighting, in years of abundant overwintered populations. Abundant coccinellids appeared immediately after aphid settling and became progressively more abundant in next two decads. Their population density was maximum in decades IV and V, when spring cereals were usually the stands most densely populated by *C. septempunctata.*

The relative coccinellid abundance in particular crops, as compared with other ones, differed annually. Thus in 1979 and 1981 the adults were more abundant in FL (in mid-May) than later on in spring cereals. In 1978 and 1980 the situation was reversed. In bean and sugar beet, coccinellid density in 1978 surpassed the density on FL and spring cereals, while in 1978 and 1979 it was only a fraction of it (especially in sugar beet). Similar disproportions were observed also on maize, where in 1978 and 1979 *C. septempunctata* adults were relatively abundant, while in 1980 and 1981 they were scarce. These differences were mainly due to relative abundance of aphid populations. Thus in FL the aphids were scarce in 1978 and 1980 (HONĚK, in press) while cereal aphids were abundant, particularly in 1978.

Also the overall abundance of *C. septempunctata* adults varied annually. The comparison could be made e. g. if we take the maximum decad density at most occupied crop in a given year as a measure of overall coccinellid density in this year. This figure attained 308.0 adults per 100 m transect in 1977 (in FL, pooled decades III and IV, HONĚK 1978a), 30.8 in 1978 (bean, decade IV), 23.9 in 1979 (FL, decade III), 9.7 in 1980 (spring cereals, decade V), and only 2.2 in 1981 (FL, decade IV). Thus the mean overall coccinellid density may vary annually by about two magnitudes. These large annual variations were caused by changes in size of overwintered populations. Their size was determined largely by suitable food and climatic conditions of the previous year, and modified by the amount of losses during hibernation, caused by the severity of winters, particularly by frosts in early spring, when the frost-resistance has already decreased (HODEK 1973).

3.2 Factors affecting adult population density

There are two causes of change in density of adults, mortality and migration. The decrease of adult population density in late June (and July) in undisturbed fields is a consequence of dying out of old overwintered adults. Population density, however, may decrease earlier due to mortality caused by human activities. In FL coccinellid density fell to nearly zero after first cutting (decades III–V). The harvest destroyed also populations of bean, which effect was particularly well visible in 1978, decade V. In sugar beet, on the other hand, the populations were destroyed by spraying against *A. fabae*, if the aphids were abundant. Extensive chemical treatments were applied in 1978 and 1981. In 1978 the coccinellid and *A. fabae* populations were smaller in sugar beet than in bean. This was a consequence of residual effects of earlier treatments with systemic insecticides against *Pegomyia betae*.

The population density of adults in FL, however, decreased also in non-harvested fields. This is visible in fig. 2, left, where data from not harvested or re-grown fields are presented only. This decrease was caused probably by emigration, due to the joint action of large increase in plant density and decrease in aphid density. The rates of reimmigration to previously harvested fields, in June, were very small, even when aphids attained extreme population densities (e. g. 25 000 *A. pisum* individuals per 100 sweeps in 1981).

3.3 Different crops as hosts of adult populations

We expressed relative populations of *C. septempunctata* adults on different crops as proportions of total adult population present on arable land in a given decad (fig. 2, right). The reason for this transformation is that crops differ not only in coccinellid population density, but also in the area on which they are grown. Thus a crop grown on a small area, although abundantly populated by coccinellids, may harbour relatively small fraction of total population present at that time at total arable land. This applies e. g. to bean, where dense *C. septempunctata* populations were usually present, but which (in Central Bohemian Region) occupies only 0.8 % of arable land. Thus its importance as a host crop for *C. septempunctata* was negligible.

After transformation it appeared that there are only two important crops that harbour large coccinellid populations: FL in decades I–IV, and spring cereals in decades III–VI. In the respective periods the stands of each of both crops may harbour up to 95 % of total adult *C. septempunctata* population of arable land. The contribution of other crops was low either due to small growing area (bean), or low coccinellid density (winter cereals), or both (potatoes). The only exception was sugar beet, which harboured up to 19 % of total population (1978, decade III). This proportion may perhaps become still higher in years when *A. fabae* is abundant while *A. pisum* and cereal aphids are scarce.

4 Discussion

4.1 The origin and displacement of adult populations

In central Bohemia, the adults found in May and June may originate virtually solely from the previous year. Only in exceptionally warm years (e. g. 1976) some adults of new generation appeared in late June (Hodek 1962). The overwintered adult population of *C. septempunctata* is partitioned between stands of agricultural crops and other plants (weeds, shrubs, forests). At present we cannot tell what fraction of total overwintered population is present on agricultural, and what one on non-agricultural land. This is due to our unability to determine precisely the population density of coccinellids in forests, and the area occupied by different weed stands. But, with respect to usually low density of *C. septempunctata* in arboreal hosts (IPERTI 1978; HONĚK and REJMÁNEK 1982) and small growing areas of weeds, we suppose that, in May and June, most *C. septempunctata* adults in central Bohemia live in stands of agricultural crops. However, before or after this period, or in different types of landscape, the abundance of *C. septempunctata* e. g. on trees may become greater (LÖVEI 1981). Thus stands other than agricultural crops may become important hosts of adult populations.

From what sources originated the populations of different crops? There are two alternatives: migration from hibernacula and migration between crops. At present we suppose that populations of most crops are founded largely by immigration from non-agricultural areas, perhaps from hibernating quarters. Even the populations of spring cereals which arise at relatively late date are perhaps largely not founded by immigrants of FL stands, at least in years when aphids on FL are sufficiently abundant. Immigrating females had not ripe ovarioles (in contrast to mostly ripe females of FL; HONĚK 1978b), and the females with ripe ovarioles have the tendency not to leave aphid infested stands unless trophic conditions had substantially deteriorated. Our preliminary experiments indicated that the flight ability of ripe females is impaired, which may be reversed by a short period of hunger.

4.2 Anthropogeneous effects on adult populations

Our results revealed the importance of agricultural practices and other human activities as potential destructors of *C. septempunctata* populations. Such influences are particularly important in crops which harbour large proportion of *C. septempunctata* population. The most important factor of destruction of adult populations ist the first cutting of FL by chopper harvesters (HONĚK 1978a). This technology destroys more than 90 % of instant coccinellid population. The cutting occurred in decade III and IV, i. e. at the time when 22 % (in 1978) to 85 % (in 1979) of total *C. septempunctata* population of arable land was present on FL. The damage depends on what part of area under FL ist harvested in this manner. Precise figures were not available, but if we counted with 60 % of area harvested by chopper harvesters, about 12–46 % of all adults on arable land could have been destroyed by the FL cutting in Central Bohemian Region in years of observation. The damages are unlikely to decrease in near future since the appropriate modifications of harvesting machines are not available. The consequence of these practices is dramatic reduction of *C. septempunctata* density on harvested fields. It is interesting that HODEK (1960) did not observe a large reduction of *C. septempunctata* density in 1955, when less destructive methods of FL cutting were applied. The losses caused through harvest of bean (from decade V onwards) and rye (decade I–II) as forage were not so important due to their small growing area.

Other sources of important damages to adult populations are chemical treatments against aphids. Their importance differ according to the intensity of treating of a particular crop and area under them (table). The most serious

The extent of chemical treatments against aphids in Czech Socialist Republic[1]

Crop	Percent of area under the crop treated 1976	1977	1978	1979
Forage leguminosae	< 0.1	0.2	< 0.1	0.6
Sugar beet				
primary infestation	104.6	3.5	46.3	5.3
secondary infestation	57.7	0.9	7.5	5.4
total	162.3	4.4	53.8	10.7
Bean	82.4	6.6	57.2	9.2
Maize	< 0.1	0.0	0.0	0.0
Potatoes	5.8	5.4	5.1	6.9
Cereals	0.4	< 0.1	0.1	0.1
Hop	558.0	495.1	558.0	436.7

[1] Bohemia and Moravia. Data of MZVž ČSR (Ministry of Agriculture and Nutrition of Czech Socialist Republic)

seems the spraying of sugar beet against *Aphis fabae*, which is inflicted at the time of maximum density of adult coccinellids. This treatment ist applied irregularly and may account for 10 % mortality of 1978 population. It kills also adults of other coccinellid species abundant in sugar beet. The negative effects on coccinellid adults may be largely decreased by the use of selective pesticides (pirimicarb). Other chemical treatments applied in central Bohemia (probably with exception of hop) seem less important due to small area under crops sprayed.

On the other hand, spring cereals are the crop which harbour largest populations of *C. septempunctata* adults. They are virtually free of negative anthropogeneous influences until harvest. They are probably the most important reservoir of *C. septempunctata*, where also convenient conditions for the development of larval populations are available. Chemical protection of cereals (against insects) in Czech republic (Bohemia and Moravia) ist still minimum (0.1–0.4 % of total area under cereals treated against all insect pests). Also the stands of maize are usually not harvested until late summer – early autumn, and the chemical treatment ist minimum. They are suitable hosts of coccinellid populations, but the quantity of *C. septempunctata*, at least the adults of overwintered population, living in these stands is small.

The distribution of *C. septempunctata* may only partially serve as a paradigm of population distribution of other common field species. They are less *(Propylaea quatuordecimpunctata)*, or more *(Coccinella quinquepunctata)* influenced by plant density (Honěk 1982). Also species depending on warm climatic conditions have perhaps particular mode of inter-crop distribution. These distributions remain to be studied before evaluating the total impact of coccinellid adults on aphid populations of field crops.

Zusammenfassung

Zur Verbreitung überwinterter Käfer von Coccinella septempunctata L. (Col., Coccinellidae) in landwirtschaftlichen Kulturen

Von 1978–81 wurde die Verbreitung der überwinterten Käferpopulationen von *C. septempunctata* in den wichtigsten Feldkulturen (Luzerne, Klee, Bohne, Zuckerrübe, Mais, Kartoffel, Sommer- und Wintergetreide) von Mittelböhmen untersucht. Die Populationsdichte wurde durch Zählung entlang einer Standardlinie ermittelt. Es wurden die mittleren Dekadendichten (1. 5.–30. 6.) bestimmt. Diese Daten wurden auf die Gesamtpopulation adulter *C. septempunctata* einer bestimmten Feldfrucht im genannten Zeitraum umgerechnet. Die wichtigsten Wirtspflanzen für überwinterte Käfer waren Luzerne und Klee (Anfang Mai bis Anfang Juni) sowie Sommergetreide (ab Ende Mai). Beträchtliche Dichtewerte wurden auch an Zuckerrübe, Bohne und Mais gefunden, doch beherbergten diese Kulturpflanzen gewöhnlich nur einen kleinen Teil der Gesamtpopulation entsprechend ihrer geringen Flächen. An Kartoffel und Wintergetreide waren die Käfer selten. Die relative Käferdichte an verschiedenen Kulturen variierte jährlich hauptsächlich in Folge der Variation der Blattlausdichte. Insgesamt variierte die Dichte von *C. septempunctata* in den Beobachtungsjahren in 2 Größenbereichen. Es wird geschlossen, daß im Mai die Käferpopulationen in den Feldern sich hauptsächlich aus überwinterten Tieren zusammensetzen. Landwirtschaftliche Maßnahmen, die die Käferdichte negativ beeinflussen, waren der erste Luzerne- und Kleeschnitt sowie chemische Maßnahmen bei Zuckerrübe gegen *Aphis fabae.*

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BUCHBESPRECHUNGEN

Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel. Hrsg. von R. Wegler. Band 6: Insektizide. Bakterizide. Oomyceten-Fungizide. Biochemische und biologische Methoden. Naturstoffe. Berlin – Heidelberg – New York: Springer Verlag 1981. XVI, 512 S. (191 in Deutsch), 165 Abb., 92 Tab. Ln. 258,– DM. ISBN 3-540-10307-4.

Band 7: Naumann, K., Chemie der synthetischen Pyrethroid-Insektizide. 1981. XI, 217 S., Geb. 168,– DM. ISBN 3-540-10452-6.

Die beiden Bände der Wegler-Reihe haben sehr unterschiedlichen Charakter. Wie es im Vorwort zu Bd. 6 heißt, könnte die Überschrift dieses Teiles „Pflanzenschutzforschung auf neuen Wegen" heißen, denn in den von 23 Autoren verfaßten 10 Artikeln wird überwiegend der neueste Stand der Entwicklung der biologischen, biotechnischen und integrierten Bekämpfungsmethoden wiedergegeben. Die meist in Englisch abgefaßten Kapitel berichten über Pheromone (3 Kap.), Juvenoide (1), Häutungshemmstoffe (1), Präparate mikrobieller Herkunft (1) und den biologischen Pflanzenschutz allgemein (1). Auch in 2 weiteren Kapiteln (Pflanzenbakteriosen und ihre Bekämpfung;