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The occurrence of the chicken mite *Dermanyssus gallinae* (Acari: Dermanyssidae) in Swiss poultry houses

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The occurrence of the chicken mite *Dermanyssus gallinae* (DE GEER, 1778) was investigated in 39 poultry houses of various types and sizes in different regions of Switzerland. Multiple regression techniques were used to search for factors possibly explaining the occurrence of the mites. Chicken mites were found in 85 % of the poultry holdings. Hygiene had a large influence on the occurrence of *D. gallinae.* The densities of *D. gallinae* were higher in deep-litter systems than in systems where scratching area and dung storing facilities (dung pit or board) were separated. In both batteries under study no *D. gallinae* were found. There was no difference in the abundance of mites between free-range and indoor systems or between small and big holdings. In the hilly northern pre-alpine region the mites were not as abundant as in the other regions. There were predatory arthropods associated with *D. gallinae,* but their role cannot be assessed with the available data.

Keywords: mite, ectoparasite, *Dermanyssus gallinae*, poultry, holding system, hygiene.

INTRODUCTION

The chicken mite *Dermanyssus gallinae* (DE GEER, 1778) is considered to be a serious problem in poultry houses. The mite is a temporary blood-sucking ectoparasite of laying hens as well as of other birds (LANCASTER & MEISCH, 1986). In poultry houses, the mites hide in cracks and crevices of the installation and attack the resting hens at night for a short blood meal. After the blood intake, the mites retire into the surroundings of the resting hens again. This behaviour of the mite implies that factors limiting the development of *D. gallinae* populations have to be sought in the poultry house as well as on the host.

The mite problems were thought to be overcome with the construction of battery systems for laying hens in the 1940-ies. However, since the battery system does not satisfy elementary behavioural requirements of the hens (FÖLSCH, 1981), it was banned by the new Swiss law for animal protection. It was presumed that in the modern holding systems, with their structured and hence more complex construction, hygiene and mites would become a problem (HAUSER, 1990). More acaricide treatments against *D. gallinae* were, therefore, thought to be necessary.

The aims of this study were to determine the spread of *D. gallinae* in Swiss poultry holdings and, second, to search for factors determining mite occurrence. The empirically identified factors limiting the development of *D. gallinae* populations were sought at different levels: geographical region, surroundings of the poultry house, construction of the holding, herd management and occurrence of predatory arthropods. The knowledge acquired by evaluating these factors shall be used to plan further research on the natural control of *D. gallinae*.

MATERIAL AND METHODS

Poultry houses under study

In summer 1989, 39 poultry houses in different regions of Switzerland were examined for the occurrence of *D. gallinae* and other arthropods. The poultry holdings were located in the following regions of Switzerland: *region* 1: Ticino (8 houses), *region* 2: Schaffhausen and Thurgau (8 houses), *region* 3: surroundings of Luzern (3 houses), Emmental (5 houses), and region between Bern and Thun (5 houses), *region* 4: surroundings of Basel (9 houses), and *region* 5: Chur (1 house). Tab. 1 shows the herd sizes and the husbandry systems of the holdings (see FÖLSCH *et al.*, 1988, for classification of the different systems).

Tab. 1: Herd sizes and holding systems of the poultry holdings under study. (F: free-range systems, I: indoor aviary systems, B: battery systems).

Number of laying hens in the herd	Number of holdings	Holding system F	I	B
1 - 25	7	7	0	0
26 - 50	3	2	1	0
51 - 100	6	5	1	0
101 - 500	9	4	5	0
501 - 1'000	3	3	0	0
1'001 - 2'000	4	3	1	0
2'001 - 4'000	6	2	3	1
>4'000	1	0	0	1

Survey data

The poultry houses were visited twice. On both occasions the temperature and relative humidity near the resting places of the hens were recorded. A questionnaire was filled out together with the farmers. It contained qualities concerning the poultry house (such as age, building materials, measurements, illumination, litter material), the hens (breed, age), and the management of the system (for instance number of laying cycles of the herd, acaricide treatments or intervals between cleaning the house) and the date of the visit. Besides the questionnaire, the factors hygiene, care and health of the chickens were judged subjectively by the investigator on a scale from 1 ('very bad') to 5 ('very good'). These variables were considered to be relevant for mite occurrence.

At the first visit of the holdings in July, four artificial mite-shelters were fixed on the perches or on the roosts, i.e. the resting places of the hens. The mite-shelters consisted of a U-shaped aluminium profile (10 cm long) which contained folded artificial buckskin. These shelters are attractive hiding places for *D. gallinae* as well as for other arthropods. After five weeks of exposure, the shelters and the arthropods inside them were removed and stored in isopropyl alcohol. The mite-shelters with the conserved mites and insects were later washed in a sieve (mesh size 125 µm). Big arthropods were removed with forceps. The remaining mites and insects were counted under a binocular as explained below.

The developmental stages of *D. gallinae* were assigned to one of three groups: 1. eggs (including damaged ones), 2. larvae and protonymphs, 3. deutonymphs, females and males. The groups 2 and 3 were later combined into one group and denoted 'mobile stages'. The insects and mites other than *D. gallinae* were separated, counted, and predatory arthropods were identified. For insects and mites the species was determined. Two predatory mites were identified by Dr. I. JUVARA-BALS (Cologny GE, CH) and Dr. A. BAKER (British Museum, London, GB). Arachnida other than Acari were assigned to their subclass.

If the shelters contained less than approximately 100 *D. gallinae*, all mites were counted. Samples containing more mites (more than 100 and less than about 5000), were counted as described by STRICKLAND (1954) for samples of aphids. Larger samples (more than about 5000) were distributed on the sieve and a subsample of $^1/_6$ was counted by the same method of STRICKLAND (1954): the mites were washed into a petri-dish which was placed over a counting grid. The samples were distributed as evenly as possible over the dish and allowed to settle for about one minute. Then the mites falling in sectors marked by the grid were counted. The sectors that were counted comprised $^1/_6$ or $^1/_{12}$ of the total surface of the dish. Ten repeated counts of two samples showed that the standard deviation was less than 10 % of the average for mobile mites in the sample.

Analysis

The occurrence of *D. gallinae* was related to poultry house data, hens, management strategies, and different regions by means of a multiple linear regression model. The two battery systems differ from the other systems in too many aspects, so they were excluded from the regression analysis.

The mean number of mobile mites per trap was calculated and $\log_{10}$-transformed:

$$y'_i = \log (y_i + 1) \qquad [1].$$

As a result, the variance of the occurrence of mobile *D. gallinae* (y) is stabilised and the residuals show no abnormal patterns (DRAPER & SMITH, 1981).

Some variables were omitted from the analysis since empirical evidence suggests that their influence is not as important as to justify a detailed analysis (e.g. type of feeder or drinker). The remaining qualitative and quantitative variables are summarised in Tab. 2 and Tab. 3. For the qualitative variables listed in Tab. 3, dummy variables were defined. Then variables considered to be redundant were excluded. Also, unreliable variables representing a momentary state were excluded from further analysis (e.g. temperature and relative humidity recorded when the holdings were visited). Data based on the opinion of the farmers had to be expelled after the detection of inconsistency with own observations. For instance, information about control measures against *D. gallinae* could not be considered in spite of its possible importance. The variables having a non-significant effect on mite num-

Tab. 2: Quantitative variables observed in poultry holdings with their units, means, standard deviations, range and, if required, the reason of exclusion from the regression model [2]. Variables marked with "+" are incorporated in the model.

Variable (x_j)	unit	mean x (± s)	range	in regression
Altitude	m above sea level	533 ± 199	203 - 910	(2)
Temperature[1]	°C	24.8 ± 2.8	20 - 30	(1)
Relative humidity[1]	%	70.2 ± 8.1	56 - 84	(1)
Age of the holding	years	15 ± 13	0 - 50	+
Laying hens	number	828 ±1'100	9 - 4'500	(4)
Density of the hens 1	hens per m^2 floor	6.0 ± 3.5	1.5 -12	+
Density of the hens 2	hens per m perch	5.7 ± 3.0	1.1 - 12	(2)
Intervals between replacing the hens	months	26 ± 13	2 - 60	(4)
Last replacement of the whole herd[2]	months bef. survey	89.5 ±138	0 - 480	(3)
Intervals between removal of dung	weeks	32 ± 33	1 - 104	+
Last removal of dung	weeks before survey	14 ± 19	0 - 78	(4)
Intervals between disinfecting	months	24 ± 11	12 - 60	(4)
Last cleaning and disinfecting	months before survey	14.5 ± 11.3	0 - 60	(4)
Last treatment with acaricide	weeks before survey	51.8 ± 59.1	1 - 260	(3)
Subjective judgement of				
- hygiene	points (sum of 2	5.8 ± 1.8	2 - 10	+
- health	judgements on a scale	6.2 ± 1.8	2 - 10	(4)
- care	from 1 - 5)	6.4 ± 1.9	2 - 10	(4)

[1] Average of two measurements. [2] Where the laying hens are replaced continuously, the variable is the same as the age of the holding.
(1) Instantaneous record; (2) expressed by other variables; (3) data unreliable; (4) R^2_{adj} decreasing when incorporating this variable.

bers according to Student's t-test (p>0.05) or leading to a decreasing R^2_{adj} when considered in the model were also excluded. Not all the variables, however, which should have been rejected on these statistical grounds, were omitted from the model. If empirical evidence suggested that a variable was important for explaining the mite occurrence, it was incorporated in the model. The selected variables are listed in Tab. 4.

As a result, the following model [2] satisfies the criteria proposed by WRIGLEY (1985), namely randomness and normal distribution of residuals, parsimony, and substantial meaning of the variables and their interactions:

Tab. 3: Qualitative variables observed in poultry holdings with their frequencies and, if required, the reason of exclusion from the regression model [2]. Variables marked with "+" are incorporated in the model.

Variable (x_j)	frequency	in regression
Region[1]		
1 / 2 / 3 / 4 / 5	8 / 8 / 13 / 9 / 1	+
Building materials of the house		
mainly wood / mainly others than wood	29 / 10	(3)
Building materials of the nests		
wood / metal	30 / 9	(4)
Building materials of the perches or roosts		
wood / others than wood	33 / 6	(4)
Litter material (scratching area)		
no litter area	2	
nothing (droppings)	5	
straw or hay	20	
sawdust or shavings	12	(4)
Litter material (nests)		
nothing / straw or hay / corn-chaff	15 / 10 / 14	(4)
Storage of the dung		
pit / board or conveyor belt / deep litter	19 / 14 / 6	+
Light		
daylight / artificial & daylight / artificial	10 / 22 / 7	(4)
Free-range system		
no / yes	13 / 26	+
Access for wild birds		
no / yes	13 / 26	(2)
Breed of the hens		
white breeds / brown breeds / diverse breeds	13 / 16 / 10	(3)

[1] See text for explanation.
(2) expressed by other variables; (3) data unreliable; (4) R^2_{adj} decreasing when incorporating this variable.

$$y'_i = \mu + \sum_{j=1}^{J} b_j x_{ij} + \sum_{h=1}^{H} c_h (x_{id} x_{ig}) + \varepsilon_i \qquad [2]$$

for $i = 1, \ldots n$, where

y'_i = log-transformed (eq. [1]) number of mobile *D. gallinae* in the i-th holding ($i = 1, ..., 37$);
μ = intercept;
b_j = regression coefficient for the j-th variable ($j = 1, 2, ..., J$);
x_{ij} = value of the j-th variable in the i-th holding;

c_h = regression coefficient for the *h*-th interaction of x_{id} with x_{ig} (h = 1, 2, ..., H);
ε_i = error term.

The parameters were estimated by least-square regression techniques with the statistical software SYSTAT®.

RESULTS AND DISCUSSION

Present knowledge on D. gallinae occurrence

The red mite of poultry is found in poultry holdings or bird nests in most parts of the world (e. g. AXTELL & ARENDS, 1990; LUNDQVIST, 1993; MUMCUOGLU & LUTSKY 1990; ZEMAN & ZELEZNY, 1980; ZEMSKAYA, 1971). Also in Switzerland, *D. gallinae* is a well known ectoparasite in commercial as well as in small poultry holdings and aviaries for decorative birds. The importance of the mite can be derived from several articles in practical journals as "Schweizerische Geflügelzeitung" and "Die Tierwelt". The mites occur frequently in holdings for laying hens according to the observations in the two Swiss animal hospitals (pers. comm. Dr. EHRSAM, Tierspital Zürich, 1988; Dr. MORGENSTERN, Tierspital Bern, 1988).

Occurrence of D. gallinae in the poultry houses under study

Counting the mites contained in the shelters is a satisfactory method for assessing the mite-density in a poultry house. This will be shown in another publication. The occurrence of *D. gallinae* in our investigation is shown in Fig. 1.

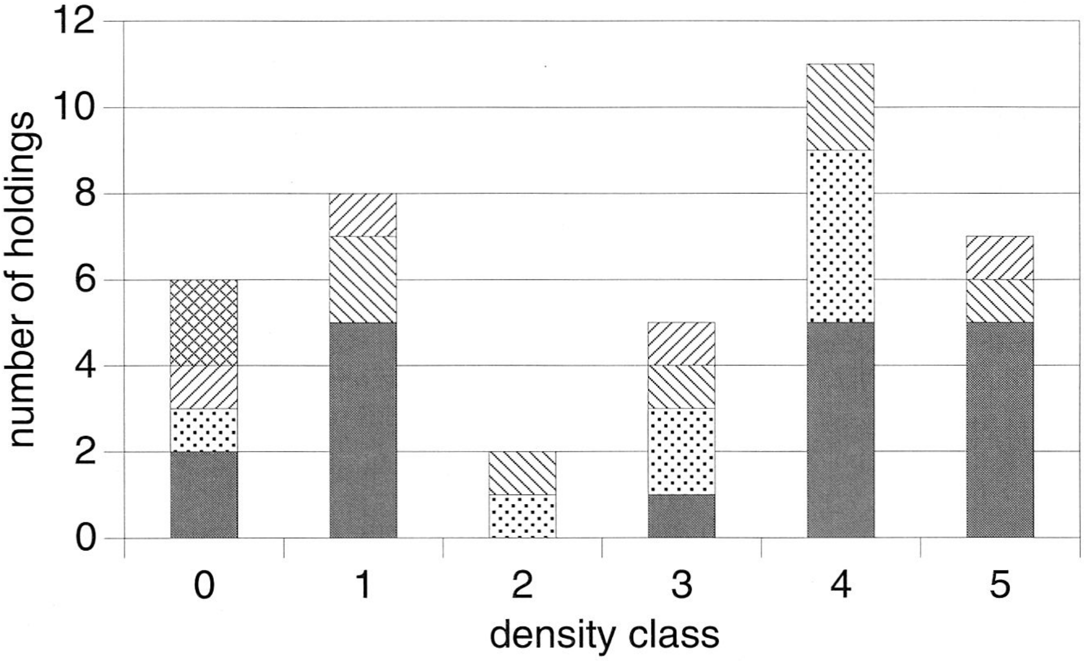

Fig. 1. The occurrence of mobile *D. gallinae* in Swiss poultry houses, separated by holding systems: ▩: battery system, ■: free-range system ≤ 500 hens, ▩: free-range system > 500 hens, ▧: indoor system ≤ 500 hens, ▨: indoor system > 500 hens. The density classes are: 0, no *D. gallinae*; 1, 1 - 50 *D. gallinae* / trap; 2, 51 - 1'000 *D. gallinae* / trap; 3, 1'001 - 10'000 *D. gallinae* / trap; 4, 10'001 - 50'000 *D. gallinae* / trap; 5, 50'001 - 100'000 *D. gallinae* / trap.

In 33 out of 39 holdings, mites were trapped during the five weeks observation period (density classes 1 - 5). In 25 holdings, more than 50 mobile mites were trapped per shelter (density classes 2 - 5), and a maximum of 84000 mobile *D. gallinae* was trapped in one holding. No relationship between the holding system (free-range, indoor, battery) and the occurrence of *D. gallinae* could be found, except for the two battery holdings, which were both free of mites (density class 0). This result has to be regarded with caution, however, as there were only two battery holdings under study and as there are also reports of serious outbreaks of *D. gallinae* in battery holdings (SCHNEIDER & HAASS, 1971; ZEMAN & ZELEZNY, 1985). Moreover, this tendency cannot have consequences for the planning of poultry houses in Switzerland because battery systems have been banned since January 1 1992 by the Swiss federal law for the protection of animals.

Tab. 2 shows the quantitative variables observed in the poultry holdings. The range of all the quantitative variables is relatively broad except for the temperature, where all the values lie within the optimum range for *D. gallinae* (MAURER & BAUMGÄRTNER, 1992). In Tab. 3, the qualitative variables recorded in the holdings are presented.

Tab. 4 shows the selection of the variables and the results of the parameter estimations. There are four quantitative variables (age of the holding, density of the hens, removal of dung, subjective judgement of hygiene), four qualitative variables (free-range system, storage of the dung in pit or on board, region; treated as dummy variables), and two interactions (storage of the dung in pit or on board x removal of dung). The model explains about 47 % of the occurrence of *D. gallinae* in the poultry holdings (R^2 corrected for degrees of freedom). Taken the complexity and the

Tab. 4: Regression statistics for the function used to describe the logarithmic (base 10) number of mobile *D. gallinae* in poultry holdings (eq. [2]).

Variable (x_j)	Coefficient	SE	t - value	p
Age of the holding	- 0.057	0.029	- 1.997	0.056
Density of the hens[1]	0.216	0.110	1.957	0.061
Removal of dung[2]	- 0.091	0.026	- 3.551	0.001
Subjective judgement of hygiene	- 0.808	0.167	- 4.849	< 0.001
Free-range system	0.740	0.728	1.018	0.318
Storage of the dung:				
in pit	- 3.372	1.311	- 2.573	0.016
on board[3]	- 2.860	1.321	- 2.165	0.040
Region 3	- 1.461	0.597	- 2.449	0.021
Interactions:				
Storage of the dung in pit x removal of dung	0.096	0.029	3.327	0.003
Storage of the dung on board x removal of dung	0.046	0.083	0.548	0.588

[1]Number of hens per m^2 floor. [2]Interval [weeks]. [3]On dung board or conveyor belt.
Intercept = 10.124; R^2 = 0.615; R^2_{adj} = 0.468.

high variability of the system into account, the model fits the data fairly well, as can be seen in Fig. 2. Because the model serves as an explanatory rather than as a predictive tool, the influence of the variables will be discussed in a qualitative way.

Region – The holdings south of the Alps do not differ from the total of the holdings north of the Alps. Yet a significant decrease of the density of *D. gallinae* ($p < 0.05$) was found in poultry houses situated in the hilly pre-alpine regions ("region 3", comprising the surroundings of Luzern, Emmental and the region

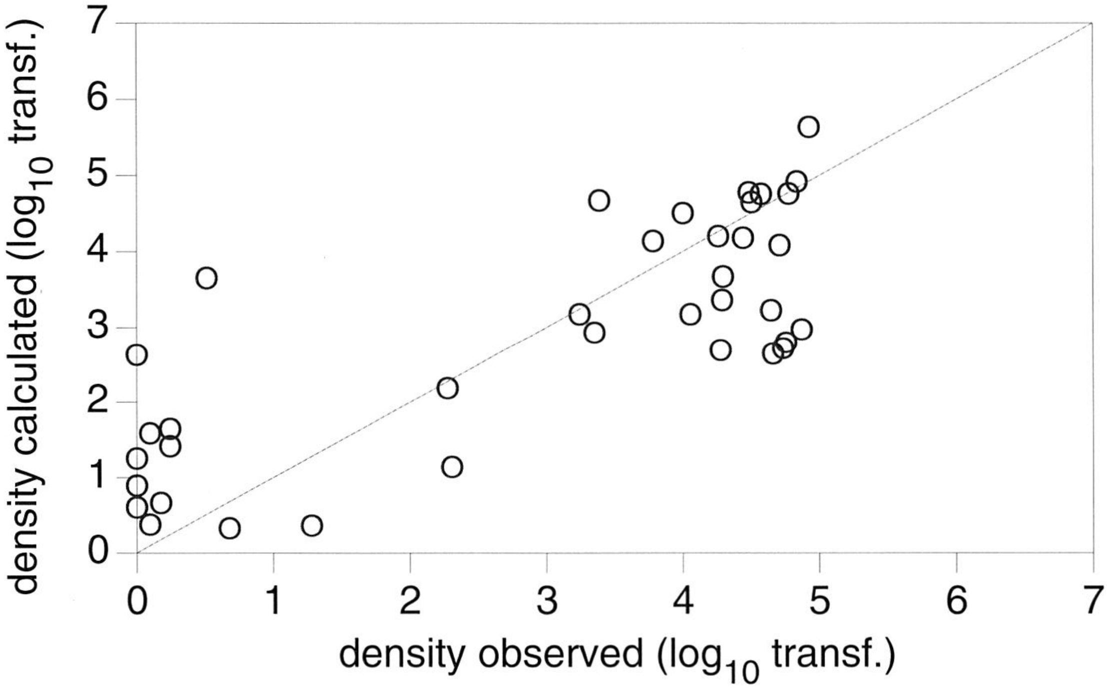

Fig. 2. Numbers of mobile *D. gallinae* observed plotted against the numbers calculated with the regression model [2]. The values are $\log_{10}$-transformed (eq. [1]). The solid line represents perfect correspondence of the model with the data.

between Bern and Thun). This difference may be due to higher altitude above sea level or higher relative humidity of the air. However, these two variables represent only a small part of the dummy variable "region 3" when they are incorporated in the model.

Poultry holding – The age of the poultry house influences the number of *D. gallinae* negatively, i. e. there are, in general, fewer mites in older holdings than in new ones. The organisation of dung storage in the houses has a very strong influence on the abundance of *D. gallinae*. If the dung is either stored in a dung pit or on a dung board (or conveyor belt) there are fewer mites than if the dung is mixed with litter material in deep-litter systems. The dummy variable "free-range system" is not significant according to Student's t-test ($p = 0.05$). Yet it is included in the model because it is supposed to have an effect on the occurrence of *D. gallinae*. The variable contains complex information that would be difficult to incorporate quantitatively (e.g. information about daylight, air quality, contact of the hens with wild birds, possibility to take a dust bath).

Herd management – There is a small but positive influence of the number of hens per m^2 on the density of *D. gallinae*. However, the availability of hosts does not seem to be a major limiting factor for the development of the mite population. Frequent removal of dung from the holding can help to reduce the occurrence of *D. gallinae*. This influence is devalued when the dung is either stored in a pit or on a dung board (positive coefficients of the interaction terms). The consequence is that frequent removal of dung reduces the development of mite populations only in deep-litter systems. Yet in systems, where the storage of dung in the house is well organised (in a pit or on a board), an increased removal-frequency has no effects on the mite population. The reason for this behaviour might be that the removal of dung also removes antagonists of *D. gallinae* living in the dung (the occurrence of predators is discussed below). The subjectively judged hygiene has a strong, clearly significant negative influence on the density of D. *gallinae* ($p < 0.001$). With increased hygiene, less mites are found in the traps. Unfortunately this important variable is difficult to quantify. Attempts to replace "hygiene" by related quantifiable variables such as "frequency of thorough cleaning and disinfecting" or "last removal of dung" result in a decreasing R^2_{adj} and in a poor fit of the model. Obviously, some important factor(s) concerning "hygiene" were not visible or were overlooked when the holdings were visited. Nevertheless, it would be inappropriate to characterise the subjective judgement of hygiene as a "random variable" and to discard it. Subjective judgements are a common approach in economy. In other research areas, such as the judgement of soils or research on forest decline, they are common tools for describing the status of a complex system (ARBEITSGEMEINSCHAFT BODENKUNDE, 1982; SANASILVA, 1986).

Occurrence of predatory arthropods

The predatory arthropods found associated with *D. gallinae* in the traps are listed in Tab. 5. The spider and the earwig *Forficula auricularia* L. (Forficulidae) were probably only temporary visitors of the trap. The tenebrionid beetle *Alphitobi-*

Tab. 5: Predatory arthropods found associated with *D. gallinae* in the traps.

Species	frequency (number of holdings)	occurrence (min-max / trap)
Insecta		
Alphitobius diaperinus	5	1 - 5
Forficula auricularia	1	1
Araneae	1	1
Pseudoscorpiones	4	1
Acari		
Cheyletus eruditus	3	3 - 24
Acaropsis sp.	5	1 - 48
Androlaelaps casalis	7	1 - 528

us diaperinus PANZER is common in the dung and litter area of poultry holdings, where it lives predaceous on other arthropods (e. g. fly larvae). *A. diaperinus* is also known to be a predator of *D. gallinae* (KOZLOV, 1970). The beetle is not tolerated in poultry houses in spite of this beneficial effects, because it migrates into the insulation material prior to pupation and destroys the material. Most of the poultry keepers therefore treat the dung area and walls with insecticides to kill *A. diaperinus*. The pseudoscorpions found in the traps are polyphagous predators of arthropods as well, and in the laboratory, they have been seen to feed on *D. gallinae*. Three species of predaceous mites were found in the traps: the two cheyletids *Cheyletus eruditus* SCHRANK and *Acaropsis* sp., and the gamasid *Androlaelaps casalis* (BERLESE). *C. eruditus* and *A. casalis* are known to be predators of *D. gallinae* from the literature (FROLOV, 1971; MCKINLEY, 1963) and from preliminary qualitative observations. The attractiveness of the artificial mite shelters for the predators is unknown, hence the reliability of the estimate for assessing the predators in the whole poultry house is low.

CONCLUSIONS

This survey has shown that *D. gallinae* is a widespread pest of laying hens also in Switzerland. The occurrence is neither limited to certain holding systems (free-range or indoor systems) nor to holding size. Yet the analysis shows the importance of a clearly structured poultry house, with a litter area separated from the area where the dung is stored. In this situation, holding systems with a dung pit do not differ from systems with a dung board as far as the occurrence of *D. gallinae* is concerned. Only in deep-litter systems the mite density can be reduced by removing the dung more frequently.

The role of the predatory arthropods in the control of *D. gallinae* cannot be assessed from this survey. To understand the relationships between predators and prey, further investigations on the population dynamics and the interactions between the species are needed.

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ZUSAMMENFASSUNG

Das Auftreten der Roten Vogelmilbe *Dermanyssus gallinae* (DE GEER, 1778) wurde in 39 Schweizer Hühnerställen untersucht. Es wurden grosse und kleine Herden und unterschiedliche Stallsysteme in die Untersuchung einbezogen. Mittels multipler Regression wurde nach Faktoren gesucht, welche zur Erklärung des Auftretens von *D. gallinae* beitragen können. In 85 % der besuchten Hühnerställe waren Rote Vogelmilben vorhanden. Die Hygiene spielt bei der Hemmung des Milbenbefalls eine wichtige Rolle. Ställe mit Tiefstreu wiesen höhere Milbendichten auf als Ställe, in welchen der Scharr- vom Kotlager-Raum (Kotgrube, -band oder -brett) getrennt war. In den beiden untersuchten Batteriehaltungen wurden keine Vogelmilben gefunden. Ansonsten unterschieden sich Haltungen mit und ohne Auslauf oder grosse und kleine Ställe bezüglich des Vogelmilbenbefalls nicht. Im hügeligen nördlichen Voralpengebiet waren weniger Vogelmilben vorhanden als in den übrigen Gebieten. Gemeinsam mit *D. gallinae* wurden auch räuberische Milben und Insekten gefangen. Ihr Einfluss auf die Vogelmilben kann anhand der vorhandenen Daten jedoch nicht beurteilt werden.

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