naltergites dunkelbraun, die Mundteile, die Basen der Fühler das erste und zweite freiliegende Abdominaltergit und die Beine hell bräunlichgelb. — Länge: 1,5 mm — Bisher nur aus Japan bekannt geworden.

kanagawaensis Scheerpeltz
1960, Ent. Arb. Mus. G. Frey,
11, 607, 614.

Zusammenfassung

Einige Staphyliniden, die vor langer Zeit von M. Bernhauer als neu erkannt und benannt, aber nicht beschrieben wurden, hat der Verfasser in dieser Arbeit untersucht, die sich als erster Teil einer Reihe von Publikationen über dieses Material zunächst mit den paläarktischen Vertretern befaßt.

Summary

A number of Staphylinid species recognized as new and named by M. Bernhauer a long time ago, but not described, are studied in this paper, which deals as a first part of series of publications on this material with the palaearctic species.

Резюме

Некоторые Staphylinidae, которые долгое время тому назад были найдены и наименованы М. БЕРНГАУЕРом, но остались неописанными, исследованы автором этой работы. Эта работа является первым рядом публикаций по этому материалу и пока занимается палеарктическими представителями.

Some Aspects of Insect Behaviour under Field Conditions I. Hatching and Migration of Caterpillars of Chilo zonellus Swinhoe[1])

(*Lepidoptera*: *Pyralidae*)

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Introduction

It is important to study the behaviour of a crop pest to save the crop from its ravages. This gives clues to economic entomologists to plan a control schedule-biological or chemical-against the pest in question. The study of the hatching of *Chilo* eggs into caterpillars needs no emphasis as that is the only point when *Chilo* starts to eat the plants and becomes an enemy of the farmer. As *Chilo zonellus* Swinhoe is a stalk borer of various crops, it is wholly exposed to its natural enemies or insecticides applied on the plant surface, only when it leaves its feeding galleries and migrates to other points of attack. The studies in migration are bound to reveal the number of chances when *Chilo* caterpillars come out and are liable to be affected by insecticides or attacked by natural enemies. Anyhow these studies are aimed at to strengthen the human efforts towards the biological as well as the chemical control of the pest.

[1]) The work formed a part of the thesis submitted in the partial fulfilment of the requirements for the Master's degree in Agricultural Zoology-Entomology of the Agra University.

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Material and Methods

Freshly emerged moths were put in oviposition cages to get egg masses for the present investigations. The oviposition cage consisted of an earthen pot containing a young growing maize (*Zea mays*) plant covered by a glass chimney with a wire gauze frame. These plants were thoroughly examined before hand to see that they were free from egg masses and the soil of the pots was free from ants and their nests. These pots were put on a bench kept in trays full of water and under the shade of a tree in the orchard. Only an egg mass was allowed to develop in each oviposition cage for observations on incubation period and hatching.

The maize crop was sown in four plots, distant from each other by 6′feet. The size of each plot was 24′ × 16′. A channel (1′wide) was dug alround each plot. Tap water was flowing in the channel throughout the period of experimentation to check the movement of caterpillars from outside to the experimental crop. All plants of these plots were thoroughly searched for egg masses which were removed (if found) before starting the experiment. All the previously damaged plants along with the larvae were thinned out. A plant was selected and tagged near the centre of each plot and an egg mass was pasted on one of its leaves. Thus four egg masses were pasted one by one in these plots and observations were taken in the migration of *Chilo* larvae. Two of them were pasted on the central straight leaves on 22nd of July and 8th of August, 1952, the third egg mass was placed on the leaf at the two third height of the plant on 30th of September, and the fourth one was pasted on the leaf at the one third height of the plant on 2nd of October, 1952. As the adult moths existing in the surrounding fields had an easy access to the plots for egg laying, a thorough search was conducted on every third day for removing these foreign egg masses to save the experimental crop from the attack by caterpillars hatched from them. All plants damaged every day by the caterpillars hatched out from the egg mass under observation were marked with a dated tag to detect the newly damaged plants on the following day. The observations were taken daily in the morning and evening till all larvae hatched out from the pasted egg masses pupated.

Observations

As the incubation period goes on increasing the colour of fertilised *Chilo* eggs in the oviposition cages changes from creamy white to brownish and finally to dark brown. At the advance stage of development if the egg mass is observed under binocular compound microscope the full formed caterpillar is visible inside the egg in the coiled condition which was also noted

Table 1. Incubation period

S.N.	Egg laying		Hatching		Incubation period in hours
	On	Started at	On	Started at	
1.	1. 8. 52	9.30 p.m.	6. 8. 52	7.30 a.m.	106
2.	6. 8. 52	8.00 p.m.	11. 8. 52	5.00 a.m.	105
3.	7. 8. 52	7.00 p.m.	11. 8. 52	9.00 a.m.	86
4.	8. 8. 52	7.30 p.m.	11. 8. 52	6.30 a.m.	59
5.	18. 8. 52	10.00 p.m.	23. 8. 52	4.30 a.m.	102.5
6.	14. 9. 52	7.00 p.m.	18. 9. 52	10.00 a.m.	87
7.	10. 10. 52	12.00 p.m.	15. 10. 52	5.00 a.m.	101
				Total	646.5
				Average	92.35

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by Lefroy (1906). The black head of the embryonic caterpillar is towards the centre and the rest of the body is along the periphery of the egg shell. The brown colour patches on the body are clearly visible under the compound microscope. All caterpillars are dorsally placed in their egg shells. Just prior to hatching the movement of the mandibles is visible and the chorion infront of them is chewed up by the mandibles. After making a hole the caterpillar begins to crawl out and the hatching is completed.

The incubation period of *Chilo* eggs averaged to be about 92.4 hours or about 4 days under field conditions. The eggs hatched one after another and the sequence of the hatching of eggs corresponded to the sequence of laying. Thus the completion of hatching of five egg masses took the varying

Table 2. Time taken in hatching of an egg mass

S.N.	Hatching			Number of eggs hatched	Time taken in hatching of an egg mass (minutes)
	On	Started at	Ended at		
1.	4. 8. 52	4.30 a.m.	5.00 a.m.	100	30
2.	5. 8. 52	5.00 a.m.	5.15 a.m.	80	15
3.	6. 8. 52	7.30 a.m.	8.15 a.m.	90	45
4.	7. 8. 52	4.45 a.m.	5.15 a.m.	30	20
5.	8. 8. 52	5.00 a.m.	5.15 a.m.	70	15
			Total	370	125
			Average for an egg-mass =		25

intervals of time depending upon the number of eggs in each egg mass and the interval between the laying of an egg and the laying of another egg just after the previous one.

In some egg masses all eggs hatched while in others few eggs did not hatch though all of them had passed through the same environmental conditions and their embryonic development was apparently complete under binocular. The egg shells after hatching were completely white with a irregular hole which was visible under magnification. The incubation and the colour changes from creamy white to brown forecast approximately the hour of the day when the hatching is to take place and migation of the larvae begins. This forecast alerts one to get ready to take observations on migration just after hatching and onwards.

There are three definite stages when the migration of the caterpillars has been observed to occur:

1. Just after hatching,
2. Before ecdysis,
3. After hibernation.

1. The caterpillars as they assumed movement after hatching started migrating in all cases towards all possible directions on the leaf surface. Some

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went along the leaf of location of the egg masses towards the stem, some towards both margins of the leaf and some towards the tip of the leaf. The most of the larvae going towards sides either turned towards stem or towards tip. Some of them went on the opposite side of the leaf and continued moving towards random directions. During movements some of the larvae had a fall and swang along a thin microscopic silken thread spun with the help of the spinneret and the salivary secretion. While hanging, their body used to remain curved like the letter J. Some of these caterpillars reached the surface of the other lower leaves directly, but when there was wind they were blown away the sufficient distances depending upon the wind velocity and reached upon the different parts of the neighbouring plants and very few of them rarely fell to the ground. Only few cases were observed when the caterpillars did neither reach any lower leaf directly, nor they were blown away to other plants due to absence of wind, but they ascended up to the place of fall along the silken thread. In climbing up the larvae used to coil up all the pre-spun silk with the help of the mouth parts and the thoracic legs. The coil of silk was easily observed by 10X hand lens. In the beginning the coil was held among the thoracic legs. When the coil was enlarged enough the larvae curved their body upwards and dragged the coil downwards with the help of the last pair of abdominal legs and kept it among the fore pairs of abdominal legs and began to fill the thoracic legs again with the new coil of silk. When thoracic legs were again filled up as before, the caterpillars transferred the silk coil again to the abdominal legs in the similar manner. Thus in few instalments the abdominal legs were also filled up with silk coils. So later on the whole lot of silk gathered in abdominal legs was dragged farther behind and left free to hang in the air still attached to their last pair of abdominal legs. The cycle of filling the thoracic legs, abdominal legs and making the coils to hang freely in the air was continued till the larvae reached the leaf surface to which the silken thread was attached at the time of fall. As soon as they reached the leaf surface they crawled normally leaving all coils of the thoracic as well as those of the abdominal legs on the leaf surface. The silk coils, which were freely hanging from the fifth abdominal pair of legs, were left hanging at the point where the larvae first caught the margin to ride on the leaf surface.

The movements of the larvae just after hatching stopped as soon as they reached the soft portion of the plant to eat. The caterpillars from the egg mass pasted on the central straight leaves migrated only few inches because they were already on the soft central whorl of leaves. They generally fed gregariously and burrowed downwards. The caterpillars from the egg masses pasted on other heights of the plants went inside the leaf sheath and reached the bud situated at each node and covered by the leaf sheath. They started feeding on them and burrowed into stem through these buds because they were the only preferred points which could be burrowed by the delicate mandibles of the first instar larvae.

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2. Prior to each ecdysis there was a period in which larvae did not feed but in an early part of the period they migrated here and there probably in search of better food for feeding voraciously during the next instar and in the later part of that period they were sitting motionless and moulting. This premoulting period was longer and longer towards pupal stage. It varied from few minutes to few days. The premoulting period prior to the first ecdysis was shortest covering few minutes only, while that prior to the pupation was the longest spreading over two to three days. The latter is known as pre-pupal period. From hatching till pupation except during the premoulting periods the caterpillars were feeding voraciously throughout the day and night and no migration was ever observed during this feeding and growing phase. In very few cases the caterpillars showed their movements only in their feeding galleries from one of its end to the other because of being disturbed by the carabid predatory larvae, but they resumed feeding immediately at the other end of the galleries and they were observed to be reluctant to come out and migrate to other places during the feeding and growing periods.

Under certain circumstances some of the grown-up caterpillars also migrated like the first instar larvae by way of hanging down and climbing up along the self-spun silk thread.

3. After the harvest of the crop the larvae had to pass through the winter season with a severe calamity inflicted upon them due to severe cold during the season. The caterpillars, which successfully survived the hibernation, were mostly those of the fifth instar and some of them were, of course, of the third and the fourth instars. During the post hibernation period it was difficult for the caterpillars of the third and the fourth instars to survive due to scarcity of the food after the winter season. As the food was their bare necessity because of the acceleration in the rate of growth based on the rise in the atmospheric temperature, they had to migrate from their hibernaculae and so they succumbed to severe mortality due to unfavourable ecological conditions of the summer season. On the contrary the full grown up caterpillars pupated in situ and did not migrate at the end of the hibernation.

The sprouting stubbles served as the destination (food) of the migrating caterpillars. In cases when the sprouts were not available in the neighbourhood, the caterpillars used to migrate upto the long distances till they got their food, otherwise they had to die when their efforts failed to provide food and shelter during the summer season.

The migration of the caterpillars from the site of the egg masses under observation during the period of experimentation resulted in the damage of the crop. The average capacity of a caterpillar to migrate and damage the crop has been measured below in the terms of the average number of plants attacked by a caterpillar.

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Tabele 3. Average number of plants attacked by a caterpillar

S.N.	Number of larvae hatched out of an egg mass,	Total number of plants damaged by caterpillars,	Average number of plants damaged by a caterpillar
1.	15	64	4.3
2.	8	26	3.3
3.	20	35	1.8
4.	12	20	1.7
		Total	11.1
		Average	2.8

In the present investigation it has been observed that the caterpillars during their all phases of migration damaged the crop at the average rate of three plants per larva.

Discussion

To observe an egg mass while the phenomenon of hatching is going on is very interesting as the nature has regulated the embryological development of all eggs in an egg mass with such accuracy that the incubation period of individual eggs in that egg mass is almost constant and that is why the principle of "first laid first hatched" has been observed. But in the table 1 the incubation period in various egg masses varies from 59 hours to 106 hours. This variation is because the laying as well as hatching of these egg masses has been on different dates with different ecological conditions in the field.

Under the conditions of the present experimentation the eggs of *Chilo* hatch in about 4 days. The incubation period observed by other workers was 3—5 days, FLETCHER & GHOSH (1919); 8—9 days, ISHIKAWA (1922); 6—7 days, VAN ZWALUWENBERG et al. (1928); 1—2 weeks, KUWAYAMA (1928); 1 week, KUWANA (1929); 8.2 and 6 days in the first and the second generations respectively, KATSUMATA (1934) and 2 days in April, 3 to 4 days in May to September and 5 days in October, RAHMAN (1944). This clearly indicates that the incubation period varies from species to species and even in the same species from season to season and from place to place due to fluctuating natural ecological conditions.

The average time taken in the eclosion of an egg has been observed to be about 20.3 seconds (from table 2), whereas the range of time taken in the completion of hatching in an egg mass has been 15 to 45 minutes. MARUMO (1932) has reported this range to be as 30 to 70 minutes. He has given 5 a.m. to 6 a. m. as the usual time for hatching and 2 p.m. to 4 p.m. as the unusual time for it and no hatching has been observed by him in the night. The morning hours has also been found suitable for hatching by MURATA (1927). TREHAN & BUTANI (1949) has reported the suitable temperature for successful hatching to be as 70 °F. to 90 °F. During the course of the present investigations the suitable time for hatching has been observed to be the morning hours from 4.30 a.m. to 10 a.m. and the range of the maximum and the

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minimum temperatures during the period of hatching has been 88 °F. to 94 °F and 67 °F. to 78 °F. respectively.

The direction of the migration of *Chilo* caterpillars has been towards the delicate and the delicious parts of the plants. The habit of caterpillars to climb up along the self spun silk thread proves that they possess the negative geotaxis, that is one of the characteristics which helps several species in searching the suitable niches for them and their progeny to thrive well. According to Lefroy (1906) the migration was affected by the size of the plant that is, "when shoots are small, one caterpillar will eat several, eating its way in and out. If shoots are large one caterpillar will find sufficient food for life in one". His observation seems to be restricted to the laboratory. Under the field conditions when the crop is young, the caterpillars are also young and no case has been observed in which a caterpillar finishes a plant and only then migrates to finish the other one. In the field the top shoots of some plants are, of course, killed (dead heart), but the rest parts of these plants are left healthy and fit to be eaten up by the caterpillars responsible for the dead hearts in them. The caterpillars do not seem to migrate due to lack of food in particular plant as some part or the other of the damaged plant is yet fit for their consumption. They do not aim at to finish one plant and then only to migrate to other. They migrate on some ground other than the quantity of food available in a plant. The reasons for migration can be better explained on the grounds of physiological instincts based on the secretion of hormones in the body of the insect and the microclimate surrounding the insect in and outside of the feeding galleries. Lefroy (1906) has further reported that generally the caterpillar may enter young cane shoots either just above ground level or at any point higher upto within say a foot from the top of the shoot. In the former case it will tunnel its way upwards until it has consumed all sappy portion of the stem when it will leave that and enter into an adjacent one. In later case it will bore down until it reaches the root stock and will pass from shoot to shoot until the period of pupation. Here he has not observed how a caterpillar migrates from shoot to shoot or from plant to plant. That is why he has been unable to observe the phenomenon of negative geotaxis in *Chilo* caterpillars. During the course of the present investigation the movements of the caterpillars inside the stem were observed to be random. In other words no caterpillar was ever found to bore throughout the length of the plant from shoot to root or vice versa in a regular fashion.

According to Rahman & Tondon (1940) the caterpillars do not migrate upto the second moult, that is, they feed gregariously, afterwards they disperse and lead a solitary life. In this case they have perhaps studied the migration of only those larvae which emerged from the egg masses oviposited on the central leaf whorl, because these were the only larvae which have been observed here to feed gregariously due to the quickest availability of the softest portion of the plant and so the migration was not very much

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marked, but some of the larvae of the first and the second instars did migrate from the central shoot as recorded in this paper. In addition to this in the larvae of the earlier instars from the egg masses on lower leaves the migration was very much marked even after hatching.

The migration studies have revealed that *Chilo* caterpillars enter the maize plants (hosts) through the top shoot when the crop is young and the central leaf whorl is delicious, but they also crawl under the leaf sheaths and search beneath it for the buds situated at the nodes to bore through them. They follow the latter route mostly when the crop is older and the various parts of the plants are fibrous, hardy and distasteful to bore through them. Taking this behaviour of *Chilo* caterpillars into consideration the scientists may be able to evolve in future a more efficient measure of control against this pest. As the genetics of maize has been studied in great detail, the geneticists may try to develop a variety with the desired character of clinging the leaf sheath to the stem more firmly than in the varieties so far evolved. This is bound to reduce the number of caterpillars to crawl into the leaf sheaths and bore the buds beneath it to get into the stem to damage the crop. If the breeding of such a variety turns out to be a success, the utilisation of the host plant resistance against *Chilo* is bound to be more economical in reducing the damage done by it. Moreover the insect control method through breeding of resistant varieties against crop pests is more or less permanent in comparison to other measures of control. So it is worthwhile to evolve a variety of maize having the above mentioned characters.

Summary

Chilo zonellus SWINHOE is one of the serious pests of maize (*Zea mays*), jowar (*Sorghum vulgare*) and sugarcane (*Saccharum officinarum*) in India. The hatching and migration of the pest during its developmental period has been studied to help in evolving the more effective means of its control. The eggs of *Chilo* hatch in the morning hours of the day. The extent of migration of caterpillars of early instars from the egg masses oviposited on the central shoot is very limited in the beginning due to the quicker availability of the food and more marked when the larvae are grown up, whereas the caterpillars of early instars from the egg masses on the lower leaves disperse immediately after hatching and later on the migration is comparatively slowed down. At the young stage of the crop all the parts of a plant are relished by the caterpillars, but when the crop is grown up the attack of *Chilo* is limited to the buds situated at each node. As the leaf sheaths covering these buds are also grown up and fibrous, the caterpillars do not like to cut the leaf sheath and reach the bud to eat, but they crawl under the leaf sheaths and then bore through the buds. The relation of the study of these habits with the possibility of breeding a resistant variety against *Chilo* has also been discussed.

Zusammenfassung

Chilo zonellus SWINHOE ist einer der gefährlichsten Schädlinge an Mais (*Zea mays*), Jowar (*Sorghum vulgare*) und Zuckerrohr (*Saccharum officinarum*) in Indien. Das Ausschlüpfen und die Wanderungen des Schädlings während seiner Entwicklung wurden näher untersucht, um wirkungsvollere Mittel zu seiner Bekämpfung schaffen zu helfen. Die Eier von *Chilo* schlüpfen in den Morgenstunden. Der Aktionsradius der jungen Larvenstadien von den Eigelegen, die auf die mittleren Schößlinge abgelegt wurden, ist anfänglich sehr beschränkt, da die Nahrung schneller erreichbar ist, wird aber größer,

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wenn die Larven erwachsen sind. Die Junglarven aus Gelegen auf den unteren Blättern hingegen verteilen sich sofort nach dem Schlüpfen, und später wird die Wanderung verhältnismäßig gering. Im jungen Entwicklungsstadium der Futterpflanze sagen alle ihre Teile den Raupen zu, aber wenn sie erwachsen ist, bleibt der Befall durch *Chilo* auf die Knospen an den Knoten beschränkt. Da die Blattscheiden, die die Knospen einschließen, ebenfalls erwachsen und faserhaltig sind, verzichten die Larven darauf, diese Blattscheiden zu befressen, um an die Knospen zu gelangen, sondern kriechen zwischen die Blattscheiden und bohren sich in die Knospen ein. Angesichts dieser Verhaltensweise wird auch die Möglichkeit erwogen, eine gegen *Chilo* resistente Rasse der Fraßpflanze zu züchten.

Резюме

Chilo zonellus Swinhoe является одним из самых опасных вредителей кукурузы (*Zea mays*), Jowar (*Sorghum vulgare*) и сахарного тростника (*Saccharum officinarum*) в Индии. Исследовались более подробно вылупление и миграции вредителя во время его развития для того, чтобы создать эффективные средства для борьбы с ним. Личинки *Chilo* вылупляются в утренние часы. Радиус действия молодых личиночных стадий яйцекладок, которые откладываются на средние побеги, в начале весьма ограничен, так как добывать корм—легко, этот радиус, однако, увеличивается, когда личинки становятся взрослыми. Молодые личинки из яйцелкадок на нижних листьях, однако, распределяются тотчас после вылупления, а затем наступающая миграция относительно незначительна. В молодой стадии развития поедаемого растения гусеницы поедают все ее части, у взрослых растений *Chilo* поражает только почки на узлах. Так как листовые влагалища, которые окружают почки, также взрозлы и волокнисты, личинки отказываются обгрызать эти листовые влагалища, чтобы дойти до почек, а влезают в листовые влагалища и вонзаются в почки. В виду этого поведения обсуждается возможность селекции устойчивого против *Chilo* вида поедаемого растения.

References

Fletcher, T. B. & Ghosh, C. C., Borer in sugarcane and rice etc. Proc. ent. Mtgs Pusa, 1919, p. 354—417, 1919.

Ishikawa, T., *Chilo simplex* in Niigata Prefecture. Niigata Agric. Exp. Sta. Special Rep., no. 15, p. 1—240, 1922.

Katsumata, K., Results of breeding experiments with *Chilo simplex* especially on the duration of the larval instars and the thermal constant. I. and II. J. Plant Prot., **21**, 35—48, 187—198, 1934.

Kuwana, S., Important insect pests of the rice crop in Japan. Proc. Pac. Sci. Congr., **4**, 201—216, 1929.

Kuwayama, S., The principal insect pests of the rice plant in Hokkaido. Bull. Hokkaido Agric. Exp. Sta., no. 47, 107 pp., 1928.

Lefroy, H. M., Moth borer in sugarcane, maize and *Sorghum* in western India. Agric. J. India, **1**, 97—113, 1906.

Marumo, I., On hatching time of *Chilo simplex*. Oyo. Dobuts Zasshi, **4**, 292—299, 1932.

Murata, J., On borers and hoppers of rice plant. J. Plant Prot., **15**, 134—146, 1927.

Rahman, K. A., Biology and control of maize and jowar borer, *Chilo zonellus* Swinhoe. Indian J. Ent., **14**, 303—307, 1944.

Rahman, K. A. & Tondon, D. N., *Chilo trypetes* Bisset (*Pyralidae*), a new pest of sugarcane from the Punjab. Indian J. Agric. Sci., **10**, 818—823, 1940.

Trehan, K. N. & Butani, D. K., Notes on the life history, bionomics and control of *Chilo zonellus* Swinhoe in Bombay Province. Indian J. Ent., **11**, 47—59, 1949.

Van Zwaluwenberg, R. H., Rust, E. W. & Rasa, J. S., Notes on the rice borer, *Chilo simplex*. Hawaii. For. Agric., **25**, 79—82, 1928.

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