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ECOLOGICAL OBSERVATIONS ON THE FREE-LIVING STAGES OF *OSTERTAGIA OSTERTAGI*

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SUMMARY

Observations were made on the development, migration and survival of the free living stages of *Ostertagia ostertagi* under natural pasture conditions in Belgium. The time for development, migration and survival was influenced by the prevailing climatic conditions. There was no development to the infective stage when the faeces were exposed on pastures from November to January. The development and migration was slow in spring and autumn and it was rapid in summer. The infective larvae could migrate laterally and vertically and at all times of the year some of the larvae were at a position on the grass blades which is suitable for grazing by the cattle. The maximum survival time for infective larvae was 14 months. The mortality was high and rapid in summer and spring and low in autumn and winter. A good number of the infective larvae, developed in the preceding pasture season, over-wintered but from April, when temperature started to rise again, their death rate increased rapidly. The period from middle of June onwards was considered to be most dangerous for a clinical and harmful level of infection. The significance of these findings in prophylaxis of ostertagiasis is indicated.

INTRODUCTION

Ostertagia ostertagi is one of the most important pathogenic nematodes of cattle in many parts of the world (PANDEY, 1972). Like other similar trichostrongylids, a part of its life cycle is passed outside the host. Since the time the eggs are passed out of the host with faeces till development to the infective stage, their subsequent survival and transmission to a susceptible host is an extremely complex process and is dependent upon the conditions prevailing in the external environment. Under natural

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conditions, on pasture plots, the development and survival of the free living stages and migration of infective larvae of *O. ostertagi* were studied, the results of which are presented in this paper.

MATERIALS AND METHODS

A. — *Pasture plot*

The experiments were carried out on a natural pasture plot at Beersel, 12 km from Brussels (Belgium), which has not been grazed by ruminants for last many years and therefore presumed to be free from any trichostrongylids of bovines.

B. — *Deposition of faecal samples on pasture plot*

Faeces collected from calves carrying mono-specific experimental infections of *O. ostertagi* were well mixed by hand so that an even distribution of eggs could be obtained. From this mixed faecal mass 5 samples of 4 gm each were examined by McMaster technique (Whitlock, 1948) and the average egg count calculated. One kg of the faeces made in the form of the pat of 15 cm diameter and 3 cm height was put on pasture. Faecal pats were exposed each month from June 1970 to June 1971 except in August 1970.

Each month faecal pats were put on the pasture : 60 in June, July, September and October of 1970 ; 30, in November, December of 1970 and January, February of 1971, 45, in March, April, May and June of 1971. The distance between two pats was 1 meter. If the height of the herbage at the beginning of a trial was more than 6 cm the pasture was mowed to 6 cm before the deposition of pats. Thereafter growth of herbage varied according to climatic conditions. Once the pats were deposited, the herbage was left to grow without mowing till the time of its collection for examination of the presence of infective larvae.

C. — *Collection and examination of faecal pats and herbage*

In the beginning of each series of the trial, faecal pats were examined at weekly or more frequent intervals, depending upon the season. Once the infective larvae had developed in the pat, the faeces and herbage were examined at fortnightly intervals. When no more infective larvae could be found in the pat on 2 consecutive examinations, only the herbage was examined thereafter, at four weekly intervals. All examinations were made in triplicate and the mean value of each finding calculated.

1. *Faecal pats.*

The faecal pat was collected carefully and its weight, consistancy and shape noted. A part of it was examined by the salt floatation method and the developmental stages noted. Another part of the pat was put in the Baerman apparatus overnight and infective larvae, if present, were counted.

2. *Herbage.*

The herbage was cut close to the ground in two lateral sections — (1) inner herbage = 6 cm around the pat ; (2) outer herbage = 6 cm around the inner herbage area. The preliminary examinations had shown that very rarely larvae are found beyond 12 cm from pat in any significant numbers. Each of this herbage was divided into 2 vertical parts (1) lower herbage (ground to 6 cm height) and (II) upper herbage (6 cm to top). Thus there were 4 samples of herbage on each examination to give an idea of the lateral and vertical migration of the infective larvae. All the sample collections from pastures were made at the same time of the day, every time between 2 to 4 p. m.

Infective larvae from each herbage sample were collected by using the Baerman apparatus, taking care to put a small quantity of herbage in each funnel and allowing it to remain overnight (Todd *et al.*, 1970).

Infective larvae were counted under a dissecting microscope. Often the sample contained many free living nematodes and the counting as such was difficult. In the beginning, equal amounts of 2 p. 100 HCl was added to kill these free nematodes (SHORB, 1937). But it was found more convenient to add 3 drops of concentrated HCl in 5 ml of suspension. This killed the free living nematodes quickly and then the actively motile infective larvae could be counted easily.

D. — *Climatological data*

The temperature at the soil surface between the herbage at the site of the experiment was recorded by thermograph (Model Lambrecht). The data on standard weather shelter temperature and precipitation were obtained from the Royal Meteorological Institute, Brussels, 6 km away from the place of the experiment at Beersel.

The experiments terminated in December 1971.

RESULTS

The data on the standard weather shelter temperature and soil level temperature under grass during experimental period are presented in figure 1 and the rainfall for the same period in figure 2.

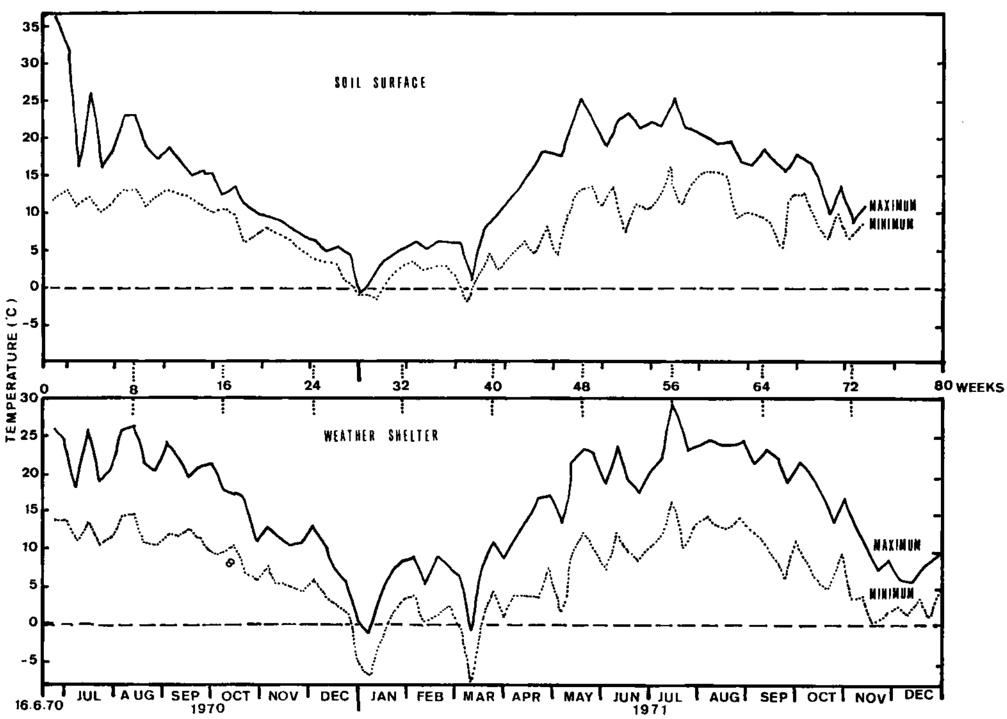


FIG. 1. — *Mean weekly maximum and minimum temperatures at soil surface under grass and in weather shelter*

Températures moyennes hebdomadaires maximales et minimales à la surface du sol et sous abri

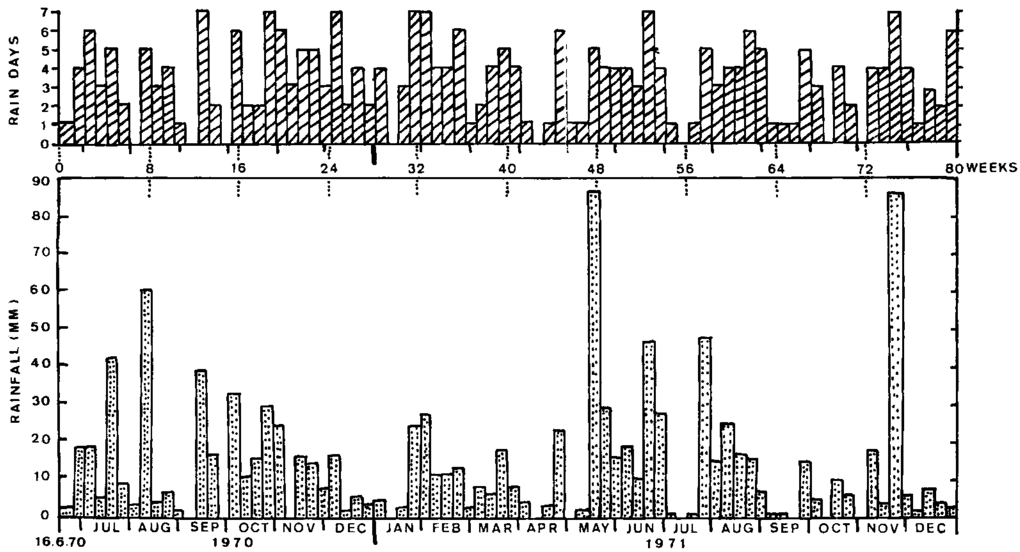


FIG. 2. — *Weekly rainfall in mm and the number of days per week during which measurable rainfall was recorded*

Pluviométrie hebdomadaire en mm et nombre de jours par semaine pendant lesquels la pluviométrie mesurable a été enregistrée

A. — *Development of the free living stages*

The rate of development was influenced by different climatic factors and considerable variations were observed according to the time of the year when faeces were exposed on the pasture. In general, the development was rapid in summer, slow in autumn and spring and stopped in winter. Table 1 presents the minimum time taken for the development of eggs to the infective stage, the maximum percentage recovery and time when such recoveries were obtained.

Broadly, the year could be divided into two periods :

a) The period during which eggs were able to develop to the infective larval stage, February to October ;

b) The period during which the eggs could not develop to the infective stage, November to January.

1. *Period during which infective larvae could develop.*

In February 1971, when faeces were exposed, the temperature was low (maximum 6°C, minimum 3°C). The majority of eggs died but a few could survive and after 12 weeks (17-5-71) 109 infective larvae were recovered from faeces and herbage.

In March, when experiments started, the mean maximum soil level temperature was 9°C (weather shelter 11°C) and the mean minimum was 4.5°C (weather shelter 4.3°C). Gradually the temperature increased to reach a mean maximum soil level temperature of 23°C and a mean minimum soil level temperature of 12.5°C by the end of May. It remained in this range with minor fluctuations till the middle of September after which it started declining. Consequently the eggs took minimum of

6 weeks to become infective larvae in March series, 3 weeks in April series, 1 to 2 weeks in May, June, July and September series and 6 weeks in October series (table 1).

For maximum larval yield, besides suitable temperature, regular and sufficient rainfall was necessary as was evident in the experimental series of July 1970 and June 1971. In July 1970, the first week after deposition of faecal pats had very little rainfall (8.2 mm in 2 days) and the second week was almost completely dry (1.7 mm on 1 day). Consequently, although some of the eggs developed to infective larval stage in 10 days, the majority of them took 5 weeks (as compared to 3 weeks in June) to become infective larvae. A similar phenomenon was observed in experimental series of June 1971. The weather was hot and dry during 3rd, 4th and 5th weeks after deposition of faecal pats on pasture. As a result, the majority of eggs needed 6 weeks (as compared to 4 weeks in May) to develop to the infective larval stage.

TABLE I

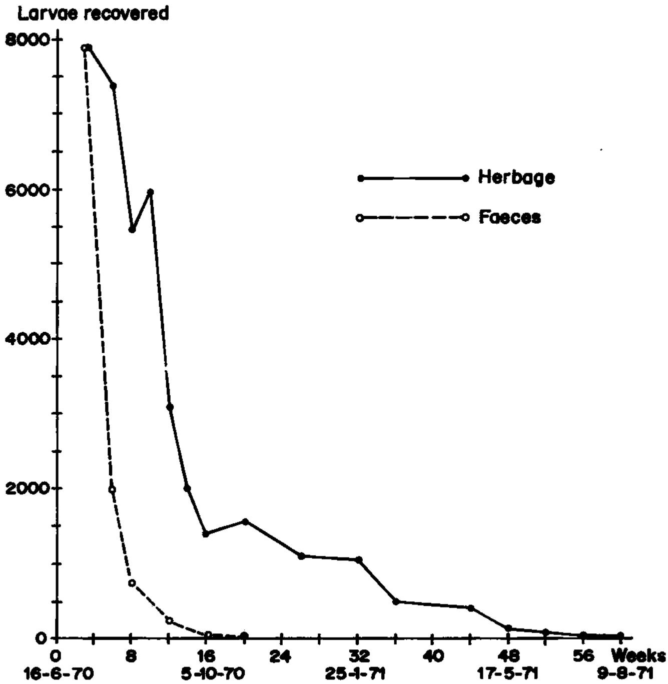
Rate of development of the free living stages of O. Ostertagi *to infective stage in faecal pats deposited on pasture at different times of the year*

Taux de développement des stades libres de O. Ostertagi *au stade infestant dans les bouses déposées sur le pâturage à différents moments de l'année*

Date of deposition of faecal pats on pasture	Minimum time taken for development to infective stage (weeks)	Maximum recovery of infective larvae (% of the total number of eggs deposited in the pat)	Weeks after deposition of faeces when maximum % of the infective larvae were recovered from the pat + herbage
June 16, 1970	1	16	3
July 20, 1970	1,5	6	5
September 14, 1970	2	5	4
October 19, 1970	6	2	10
November 24, 1970			
December 15, 1970	Nº development to the infective stage		
January 20, 1971			
February 22, 1971	12	0,1	12
March 22, 1971	6	10	8
April 19, 1971	3	13	4
May 17, 1971	1.5	6.5	4
June 14, 1971	2	7.6	6
Date de dépôt des bouses sur le pâturage	*Temps minimum pour le développement du stade infestant (semaines)*	*Récolte maximum de larves infestantes (% du nombre total d'œufs déposés dans la bouse)*	*Semaines après dépôt des fèces lorsque le maximum % de larves infestantes sont récoltées à partir de la bouse + plante*

2. *Period during which infective larvae could not develop.*

In November and December, during the experimental period, the mean maximum soil level temperature was between 7°C to 5°C and the mean minimum soil level



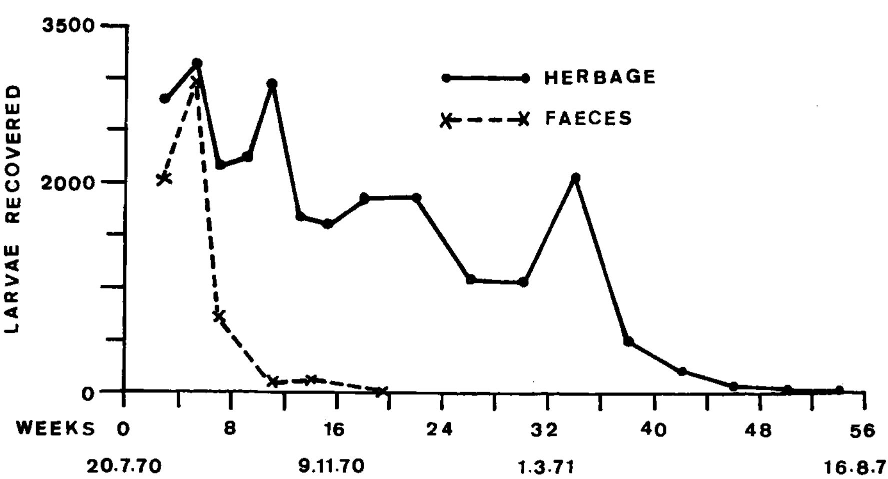
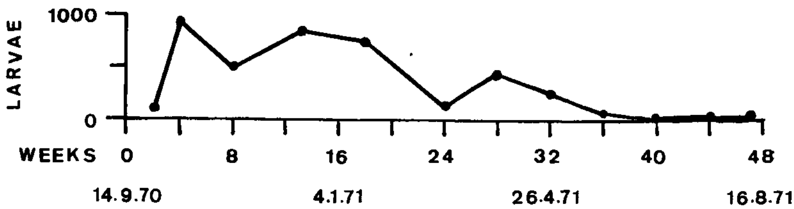


FIG. 3, 4. — *Recovery of infective larvae of* O. ostertagi *in experiments started in June* (fig. 3), *July* (fig. 4) *1970*

Récolte de larves infestantes de O. ostertagi *au cours d'expériences commencées en juin* (fig. 3), *juillet* (fig. 4) *1970*



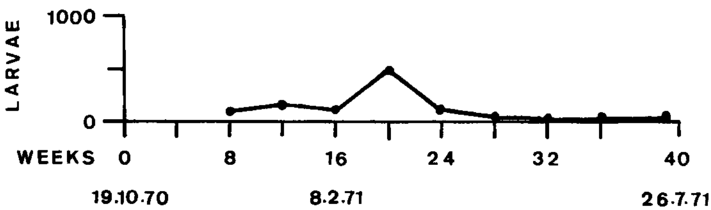


FIG. 5, 6. — *Recovery of infective larvae of* O. ostertagi *in experiments started in September* (fig. 5) *and October* (fig. 6) *1970*

Récolte de larves infestantes de O. ostertagi *au cours d'expériences commencées en septembre* (fig. 5) *et octobre* (fig. 6) *1970*

temperature between 5°C to 3°C. There was partial development of the eggs and a small percentage of them (2 to 5 p. 100) could embryonate, hatch and develop to the pre-infective stage.

In January 1971, the mean maximum and minimum soil level temperatures were 5°C and 1°C respectively. The development of the eggs at such temperatures was stopped and they could never develop beyond gastrula stage.

B. — *Migration of infective larvae*

a) *Migration of infective larvae from faecal pats to the herbage.*

The rate of migration of infective larvae from faecal pats on to the herbage varied according to the season.

As it has been stated earlier there was no development of the eggs to the infective larvae from November to January and therefore question of migration does not concern this period.

In February 1971, the larval recovery was so low that no conclusive opinion could be formed on migration of the larvae. On only one occasion 9 infective larvae were found on herbage, 12 weeks after start of the experiments.

In the exprimental series of March 1971, the infective larvae started migriting out of the pat in the middle of the May but the larval herbage peak reached only by middle of June (12 weeks after deposition of faecal pats on pasture).

In April 1971 series, the migration of infective larvae from pats started 4 weeks after deposition of these pats on pasture and the herbage larval peak reached by the middle of June (8 weeks after start of the experiments).

In May 1971 series, the herbage larval peak reached after 4 weeks of deposition of pats on pasture.

An examination of findings of March, April and May series shows that the peak larval herbage infestation reached in the middle of June irrespective of whether the faecal pats were deposited on pasture in March, April or May (fig. 7, 8 and 9).

The peak herbage larval yield was recorded after 3,5 and 4 weeks in the experimental series of June, July and September 1970 respectively. In experimental series of October 1970, the migration of infective larvae was very slow and the peak herbage larval infestation reached 10 weeks (in March 1971) after start of the experiments.

The results of the exprimental series of June 1971 merit special mention. Eggs in the pats deposited in the month of June 1971 developed to infective stage after

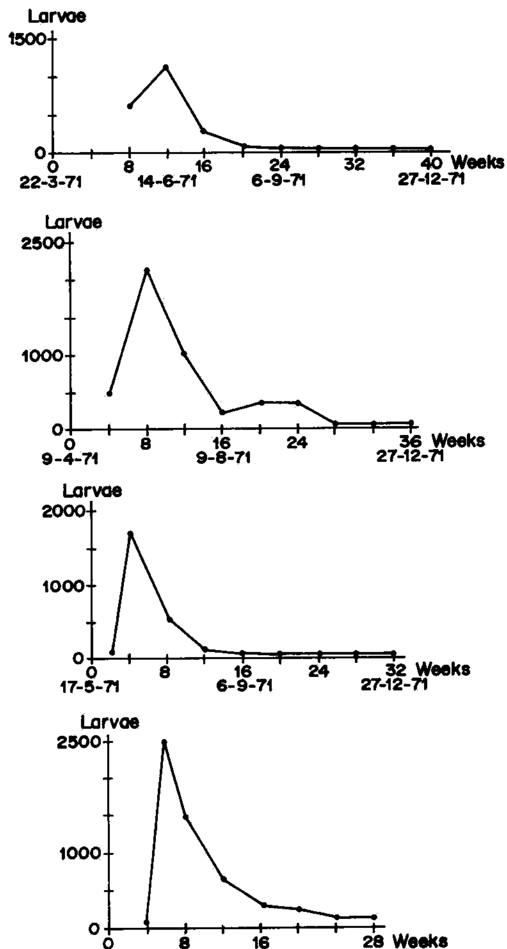


FIG. 7, 8, 9, 10. — *Recovery of infective larvae of* O. ostertagi *from herbage in experiments started in March* (fig. 7), *April* (fig. 8), *May* (fig. 9) *and June* (fig. 10) *1971*

Récoltes de larves infestantes de O. ostertagi *sur des plantes au cours d'expériences commencées en mars* (fig. 7), *avril* (fig. 8), *mai* (fig. 9) *et juin* (fig. 10) *1971*

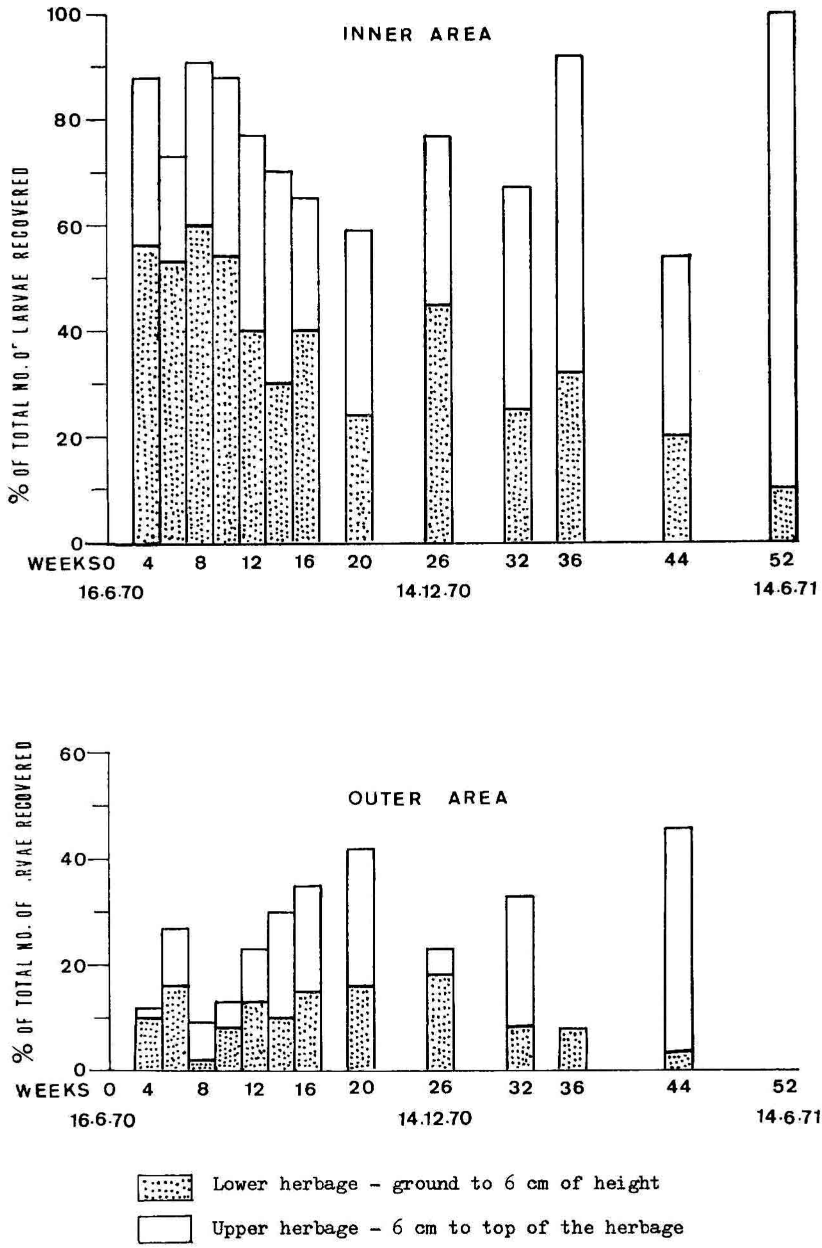


FIG. 11. — *Lateral and vertical distribution of infective larvae of* O. ostertagi *on herbage in experiments started in June* 1970
Inner area extended 6 cm around the faecal pat and the outer area from 6 cm to 12 cm around the pat

Répartition latérale et verticale des larves infestantes de O. ostertagi *sur les plantes au cours d'expériences commencées en juin* 1970
La zone intérieure autour de la bouse s'étend à 6 cm et la zone extérieure de 6 à 12 cm

2 weeks. The weather was very dry without any rainfall during 3rd, 4th and 5th weeks. Consequently, faecal pats dried up and the outer surface became hard and crusty. The pats had lost 50 p. 100 of their weight by the 3rd week and 88 p. 100 by the 5th week. Under such conditions the larvae could not leave the pat. Herbage examination on the 4th week revealed only 8 infective larvae. During the 6th week, 48 mm of rain fell in 5 days. The pats became soft and humid and there was a sudden heavy migration of the larvae from the pat with the result that the peak herbage infestation reached by the end of the 6th week, on 26-7-71 (fig. 10). The number of larvae in faecal pats has declined corresponding with their increase on the herbage.

It is evident from these observations that the infective larvae are not able to move out of the faecal pats if these are dry, hard and crusty and therefore rainfall is an important factor in this process as it helps the larvae to leave the pat by keeping it humid and soft.

b) *Lateral migration of the infective larvae on the herbage.*

The lateral and vertical distribution of larvae on herbage are presented in figure 11 for the experiments starded in June 1970. The pattern was identical in other months.

Majority of the larvae were recovered from the « inner » area of the herbage, having migrated up to 6 cm around the pats. A small percentage of them did migrate farther and were recovered from the « outer » area. Although few larvae could migrate farther than 12 cm, the preliminary experiments had shown that their number was so low that no useful purpose could be served by examining the herbage beyond 12 cm. There were some variations in the proportions of the larvae found in the « inner » and the « outer » areas but the general pattern was almost similar during different periods of the year.

c) *Vertical migration of the infective larvae on the herbage.*

The larvae could migrate vertically on grass blades. In the experiments started in June 1970 higher number of larvae were found on the lower herbage whereas in the experiments started in July, in general, more of them were found on the upper herbage. This pattern of vertical distribution was similar in « inner » and « outer » areas. The number of larvae in the series of September and October experiments was low but majority of them were always found on the lower herbage. In the exprimental series of March, April and May a relatively high percentage of larvae were on the lower herbage. However those in the outer area were mostly found on the upper herbage. The larvae in the experimental series of June 1971 were distributed almost equally on the lower and upper herbage.

It is clear from these observations that some of the larvae are always found on the herbage 6 cm above the ground surface.

C. — *Survival of infective larvae*

a) *Survival of infective larvae in the faecal pats.*

The length of time during which infective larvae were recovered from faecal pats and the time needed for their disintegration are presented in table 2.

Infective larvae were never detected in the pats exposed in November, December and January. From the pats exposed in February only once, 100 infective larvae were recovered.

The loss of infective larvae from faecal pats may be due to two reasons : migration on to the herbage and death. If weather conditions were favourable, most of the larvae had migrated on to the herbage soon after their development and only a small number could be recovered for such a long period as indicated in table 2.

TABLE 2

Disintegration of faecal pats and time during which infective larvae were recovered from them

Désintégration des bouses et temps durant lequel les larves infestantes sont récoltées à partir de ces bouses

Date of deposition of faecal pats on pasture	Time taken for disintegration of faecal pats (weeks)	Period during which infective larvae were recovered from pats (weeks)
June 16, 1970	36	12
July 20, 1970	30	13
October 19, 1970	34	16
November 24, 1970	29	No development
December 15, 1970	28	to the infective stage
January 20, 1971	27	
February 22, 1971	20	12
March 22, 1971	17	12
April 19, 1971	13	8
May 17, 1971	12	10
June 14, 1971	13	9
Date de dépôt des bouses sur le pâturage	*Temps nécessaire pour la désintégration des bouses (semaines)*	*Période durant laquelle les larves infestantes sont récoltées dans les bouses (semaines)*

b) *Survival of infective larvae on the herbage.*

The infective larvae on the herbage, in the experiments, started in June, July, September and October 1970 survived till August 1971 (fig. 3, 4, 5, 6), *i. e.*, maximum survival was 14 months. The larvae in these series resisted well the winter conditions. But with the arrival of spring, mortality increased and by the end of June 1971 most of the overwintered larvae were dead. Only a few of them were alive till August 1971. In experimental series of June 1970 (fig. 3) peak larval recovery reached on 6-7-70 and in the following months a high mortality of larvae occurred. More than 50 p. 100 of the larvae survived till 24-8-70, 10 weeks after deposition of feces on pasture. The mortality was more rapid after that time so that by the beginning of autumn (5-10-70) only 18 p. 100 of the larvae were surviving. In autumn the mortality was very low and by the end of December still 14 p. 100 of the larvae were alive. In winter months the larvae survived well. After 19-4-71 the death rate increased again and by the end of spring only a very small number of larvae were recovered from the herbage. However, small numbers continued to be recovered till August 1971.

In the experimental series of July 1970 (fig. 4), a high level of herbage infestation was maintained till 7-10-70. The mortality was relatively low in autumn and about 60 p. 100 of the larvae were alive on 21-12-70, 5 months after deposition of the pat. With certain fluctuations a similar high level of infestation was maintained till the beginning of spring. In spring, the death rate was similar to that of June series with a low recovery till the beginning of August 1971.

In the experimental series of September and October the infective larvae survived well the autumn and winter but with the arrival of spring their mortality increased and by the end of June all, except few, perished (fig. 5, 6).

From November to January, when pats were exposed, there was complete mortality of pre-infective stages and infective larvae could not develop.

In the pats exposed in February also, the mortality of pre-infective stages was high and on only one occasion on 17-5-1971, 3 months after deposition of pats on pasture, 9 larvae from the herbage and 100 in the pat were recovered.

The survival of the infective larvae in the experiments started in March, April and May 1971 followed an identical pattern.

In the experiments started in March (fig. 7) and April (fig. 8), the mortality of the infective larvae was very high from middle of May to middle of June. Eighty-five percent of the larvae died during this period. After middle of June, no more larvae could be recovered in the faecal pats and the herbage infestation reached its peak at this time. The drop in the herbage infestation after that was quick and by the 4th week of July, 1.5 p. 100 of the larvae of March experiment and 1 p. 100 of the April experiment were surviving on the herbage. Thereafter a low number of larvae survived till December.

In the June 1971 series, after the peak larval recovery from the faecal pats and the herbage on 26-7-1971, in the next month the mortality was heavy and 66 p. 100 of total larvae died during this period. The death of the larvae continued at a slower rate till October, 9 p. 100 of the larvae survived till the end of September and about 5 p. 100 till October. From September till December relatively a constant number of larvae was maintained on the herbage.

DISCUSSION

ROSE (1961) defined « translation » as the process whereby eggs in the faeces become infective larvae on herbage available to the grazing animal. This is an extremely complex process involving the development, migration and survival of the free living stages which in turn are influenced by climatic factors. Besides the climate, such factors as the predators (e. g. dung beetles, predatory fungi etc.) may also play an important role in this process.

It was evident by the regular examination of the pats that faecal deposits contained a large number of organisms. Although no attempt was made to study the fauna of the pat, it was found that a great variety of organisms lived in association with it. Annelids, dung beetles, different fly larvae, snails, slugs, arachnids, ants, collembola, mites, free living nematodes, bacteria, protozoa and fungi were encountered in the pats. The nature and number of the different organisms varied according to the climatic conditions. Occasionally the dung beetles had hollowed out the dung pats and therefore it was no more compact, rather it was converted into small pieces. This exposed the free living stages of *O. ostertagi* to increased effects of evaporation leading to high mortality of pre-infective larvae. Some of these organisms are predators on nematode larvae. The predatory role of many of these organisms is not yet known. However it is highly probable that they might have affected the number of larvae available in the pats and thereby the infectivity of the pasture.

REINECKE (1960), in a field study in South Africa, demonstrated that the presence of dung beetles reduces the number of infective larvae in the faeces. We have found that the predatory fungi are also very effective in reducing the number of infective larvae (PANDEY, 1973). Unfortunately very little work has been done on the effect of various organisms on the free living stages of trichostrongylids.

A. — *Development of infective larvae*

The present experiments show that the infective larvae are able to develop in the faeces deposited on pasture during 9 months of the year, no development being completed during the months of November, December and January. Although when faeces are exposed in February, development is possible but the extent is so low that it is of no significance.

1. *Effect of temperature.*

Temperature has a marked effect on the rate of development. Soil level temperature is a better indicator of conditions prevailing at the microhabitat of the free living stages and is, therefore, of much importance than the weather shelter temperature taken at a level much higher than the actual habitat of these stages. ANDERSEN *et al.* (1970) in U. S. A. and PACENOVSKY *et al.* (1971) in Holland arrived at similar conclusions.

Temperature was the main cause of variations in the rate of development observed in the present experiments. It rises in spring and, by the end of April, conditions suitable, although not optimum, for development are present. The temperature continues to increase from May to August and then falls in the autumn. This is the general pattern but variations from year to year in the same month may occur. The temperature in June of 1970 was higher than that of 1971 with the result that the eggs developed to the infective stage more rapidly in June 1970 than in June 1971. Therefore the results may not be generalized. However, normally the variations between years are in such a range that it may be assumed that the rate of development of eggs to infective larvae will increase from May to August.

The effect of rising temperatures on development was shown in the experiments started in March and April. In March and April, temperature was low and larval development was very slow. When in the beginning of May temperature rose, the eggs developed to infective stage. Thus irrespective of the time when faeces were exposed, the maximum number of infective larvae in faecal pats developed by the middle of May. If herbage infestation is considered, it reached its peak in the middle of June irrespective of whether the faeces were put on pasture in March, April or May. Due to the effect of decreasing temperatures from September onwards, only a very small number of infective larvae were able to develop.

One of the earliest workers, MONNIG (1930) has demonstrated the inability of sheep *Trichostrongylus* spp. (a genus close to *Ostertagia*) eggs to develop to infective stage during cold months in South Africa. But ROSE (1961) in England observed that the infective larvae could develop in the faeces deposited from November to January after an interval of 8 to 20 weeks. In present experiments there was complete absence of development to infective stage in the pats deposited during this period.

2. *Effect of rainfall.*

Rainfall is another important climatic factor in the translation process as it influences the development, survival and migration of infective larvae on to the herbage. ROBERTS *et al.* (1952) considered that there was sufficient moisture in the faecal pats and rain was not necessary for development of eggs to the infective stage. They were of the opinion that rain may be required for the movement of the larvae on to the herbage. DURIE (1961) confirmed their findings with a remark that under such conditions the percentage recovery of larvae would be very small. Observations in the present work confirm the conclusions of DURIE (1961).

B. — *Migration of infective larvae*

Migration of larvae from faecal pats is necessary for transmission of the infection to animals.

1. *Role of rainfall.*

Rain is necessary for higher larval yield and no migration would occur in its absence because the surface of the pats becomes hard and crusty. This fact was well illustrated in the experiment started in June 1971. The infective larvae developed in 2-3 weeks. The weather was dry and therefore soon after development of infective larvae, pats became dry, hard and crusty and no migration could occur. The infective larvae did not leave the pat till the 5th week. It was only in the 6th week when sufficient rain fell, the larvae migrated quickly on to the herbage. If rainfall is heavy and regular, the herbage infestation rises quickly as seen in June and July 1970. The amount and frequency of rain in the following few weeks after deposition of the pats is of more significance in the summer months. It was observed that the faecal pats lost weight quickly of rain was absent even for few days and the larval recovery was always low from such pats.

2. *Lateral and vertical migration.*

To be available to the grazing animal the infective larvae must be located at a suitable position on the grass blades. The infective larvae could migrate laterally as well as vertically. Recently GEVREY (1970), working in Lyon (France), has made a detailed study of factors determining the vertical migration of infective larvae of « Strongles » of sheep. In our experiments, during all the seasons majority of infective larvae were situated in the area close to the faecal pats. Some of the larvae, however, were always found in the « outer » area. In both the inner and outer areas a good number of larvae were located on the herbage 6 cm above the ground level. It would appear, therefore, that only a relatively small proportion of total larvae on herbage are located at a favourable situation for ingestion by the grazing animal. The real and exact significance of distribution of larvae on the herbage in relation to the infection is difficult to interpret. In any attempt to interpret such results at least 3 factors should be considered :

1) grazing behaviour of cattle ;
2) condition and growth of pasture and ;
3) stocking rate.

Normally when keep is good and sufficient grass is available bovines avoid the herbage near the faecal pat and do not graze close to the ground. But in case of poor pasture and high stocking rate they are less selective in their grazing behaviour and then will even ingest the tussocks of herbage around the pat, where most of larvae are located. The growth of herbage as such results in the reduction of intake of larvae by the grazing animal, because the number of larvae per unit weight of grass is diluted. But this dilution factor is counterbalanced by the fact that high herbage provides a more favourable micro-climate for the development and migration of infective larvae.

C. — *Survival of infective larvae*

The infective larvae survived for a long time on pasture. The maximum longevity observed in the present work was about 14 months. Various American workers (BAKER, 1939 ; GOLDBERG and RUBIN, 1956 ; DRUDGE *et al.*, 1958 ; GOLDBERG, 1968 ; WILLIAMS and BILKOVICH, 1971) have demonstrated that *O. ostertagi* larvae can survive on pasture for up to 9 months. ROSE (1961), in England, observed that a large number of *O. ostertagi* larvae could survive for 8 months and a few up to 2 years. KUTZER (1967) found that in Austria these larvae could survive for 11 months, whereas KLOOSTERMAN (1971) and PACENOVSKY *et al.* (1971) showed that a large number of larvae could over-winter in Holland. The lenght of survival in Belgium corresponds very close to those observed in other regions of temperate zone of Europe.

The survival of infective larvae on pasture was influenced by climatic conditions. It was observed that mortality of the larvae was high during summer months. But this was recompensated by favourable conditions for development. The death rate was low during autumn and winter. From April onwards, when temperature started to rise, there was high mortality of larvae. It is evident from the present observations that only a small number of eggs are able to develop to infective larvae from September onwards and they contribute very little to the herbage infestation. The bulk of the larvae on herbage in autumn would, therefore, be those which have developed before September.

The over-wintered infection results mainly from faeces deposited during the summer months and very little contribution is made by those deposited in late grazing season. Working in field conditions in England, MICHEL (1969), MICHEL *et al.* (1970) and ROSE (1970) arrived at similar results. In Holland, PACENOVSKY *et al.* (1971) showed that over-wintered infection results mainly from faeces deposited during autumn months. They attributed this difference between England and Holland due to variations in relative predominance of *O. ostertagi* and *Cooperia oncophora* in two countries. *C. oncophora* was the predominant species in Holland which survives better than *O. ostertagi* (ROSE, 1963 ; KLOOSTERMAN, 1971).

D. — *Practical consequences of the present study*

The infective larvae which have over-wintered provide the source of infection for young clean calves turned on the pasture in spring. The herbage infestation in the present observations dropped to a low level in the beginning of may. However, if the young calves are turned on pasture early in April, a relatively high number of larvae are still available and a more higher infection will be built quickly. These over-wintered larvae are available on herbage till August. Therefore, if the calves are turned on pasture even in June or July they will get infected. Such experiences were gathered in the epidemiological studies in 1969 grazing season in Belgium (PANDEY, 1972). The calves put on pasture in June were infected quickly by the overwintered larvae. However the extent of infection is always low in the beginning of pasture season.

The eggs deposited on pasture from March to May make a significant herbage infestation by the middle of June. MICHEL *et al.* (1970) found that in the north east of England dangerous herbage infestation did not reach before middle of July but in the south west England it reached by the middle of June. The results of the present investigation correspond, therefore, to that of the south west of England. This period is dangerous because a large number of infective larvae developed from eggs deposited on pasture over many weeks become available on the herbage at one time. The conditions for development and migration from middle of June to August are normally much favourable. Thus it is clear that the middle of the season is the dangerous period for heavy infections especially for non resistant young calves. In epidemiological studies in 1969 in Belgium, it was found that, in some farms, calves turned on pasture in the beginning of May had already developed a high egg count by the middle of June. In some other farms the peak egg count reached in the middle of July. The eggs passed out from infected host in June and July will be available on herbage in an average period of 2-3 weeks. Consequently, a dangerous level of infection may be picked up and clinical disease may appear at any time from July onwards. These assumptions were proved in the epidemiological studies in 1969. In some of the farms the young calves first time on pasture developed a clinical disease and some of them died in the month of September (PANDEY, 1972).

Suggestions for prophylaxis of ostertagiasis.

The objective of any control method for ostertagiasis should be to withhold the young non-resistant calves from picking up heavy infections which are built up from the middle of June. A judicious procedure in Belgium would, therefore, be to move these calves from infected pasture to a clean pasture by the end of June and at the same time dosing them with an anthelmintic. Since none of the present anthelmintics are 100 p. 100 effective against immature stages, a second dose, a week after, should be given. They may need a second movement to a clean pasture and a second anthelmintic treatment later in the season, should the larval herbage infestation on the second pasture rise high. One has to keep a vigilant eye on the weather and condition of the calves to make any local modification in the plan of prophylaxis as the conditions may vary from year to year.

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RÉSUMÉ

OBSERVATIONS ÉCOLOGIQUES SUR LES STADES LARVAIRES LIBRES D'*OSTERTAGIA OSTERTAGI*

Le développement, le déplacement et la survie des stades larvaires libres d'*Ostertagia ostertagi* ont été étudiés sur une prairie naturelle près de Bruxelles. Le développement, le déplacement et la survie sont influencés par les facteurs climatiques. Dans les matières fécales exposées sur la prairie de novembre à janvier, les larves infestantes ne se développent pas. Le développement et le déplacement des larves infestantes étaient lents au printemps et en automne et rapides en été. Les larves infestantes peuvent migrer latéralement et verticalement. Pendant toute l'année, quelques larves peuvent être présentes sur les herbes du pâturage. La survie maximale des larves infestantes est de 14 mois. La mortalité des larves est élevée et rapide en été et au printemps, lente en automne et en hiver. Un bon nombre de larves infestantes résistent pendant l'hiver mais leur mortalité augmente à partir d'avril quand la température s'élève à nouveau. La période à partir de mi-juin est considérée comme la plus dangereuse pour une infestation clinique. L'utilité pratique de cette observation dans la prophylaxie de l'Ostertagiose des bovins est indiquée.

РЕЗЮМЕ

Экологические наблюдения над свободными личиночными стадиями *Ostertagia ostertagi.*

Развитие, передвижение и выживаемость свободных стадий личинок *Ostertagia ostertagi* изучались в природе на луге недалеко от Брюсселя. Климатические факторы отражаются на развитие, передвижение и выживаемость личинок. В каловых массах находящихся на луге с ноября по январь месяц, заразные личинки не развиваются. Весной и осенью они развиваются и передвигаются медленно, а летом очень быстро. Инвазия личинками может распространятся в вертикальном и побочном направлениях. Личинки могут оставаться в траве постоянного пастбища в течении круглого года, но выживаемость инфекцирующих личинок не может пре-

вышать 14-ти месяцев. Летом и весной смертность личинок происходит очень быстро и она большая, зимой и осенью этот процесс медленный и смертность гораздо меньше. Большое количество этих личинок выдерживает зиму, но с апреля их смертность увеличивается, когда температура снова повышается. Самым опасным временем года, для клинической инвазии, считают период начинающийся в половине июня. Практическое применение данных наблюдений в профилактике остертажиоза крупного рогатого скота считается необходимым.

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