The influence of hydro-meteorological conditions on the spread of chicken cestodiasis

M. V. Bogach*, A. P. Paliy**, L. V. Perots’ka***, I. V. Pyyovarova****, V. Y. Stoyanova*, A. P. Paliy*****

*Odessa Experimental Station National Scientific Center "Institute of Experimental and Clinical Veterinary Medicine", Odessa, Ukraine
**National Scientific Center "Institute of Experimental and Clinical Veterinary Medicine", Kharkiv, Ukraine
***Odessa State Agrarian University, Odessa, Ukraine
****Kharkiv Petro Vasylenko National Technical University of Agriculture, Kharkiv, Ukraine
*****Kharkiv National University of Industrial and Foreign Trade, Kharkiv, Ukraine

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Introduction

In recent years the poultry industry in Ukraine has experienced stable and confident development and hence, duces, geese, turkeys, quails, guinea fowl and ostriches are kept on small farms as well as large. However, modern progressive poultry rearing technology has led to a number of new production problems associated with the decrease in its viability and productivity and has a number of environmental hazards (Sonntag et al., 2019). Thus a whole series of pollutants, pathogenic and conditionally pathogenic microorganisms, helminths, eggs and synthetic hormones, veterinary antimicrobial agents and heavy metals are excreted from the birds’ manure and all of them can reach the surface of soils in local agricultural land, surface and ground waters and pose direct and indirect risks to human health (Hu et al., 2017). It was determined that the average level of soil pollution in rural areas with helminth eggs (strongylids) and ascaridoids, trichocephaloids, cestodes and trematodes) is 12.5% (Paliy et al., 2019). Thus a whole series of pollutants, pathogenic and conditionally pathogenic microorganisms, helminths, eggs and synthetic hormones, veterinary antimicrobial agents and heavy metals are excreted from the birds’ manure and all of them can reach the surface of soils in local agricultural land, surface and ground waters and pose direct and indirect risks to human health (Hu et al., 2017). It was determined that the average level of soil pollution in rural areas with helminth eggs (strongylids) and ascaridoids, trichocephaloids, cestodes and trematodes) is 12.5% (Paliy et al., 2019).

Today one of the important problems in poultry farming and bird keeping both in homesteads and on farms is the spread of endoparasites, which cause a significant decrease in productivity and significant economic damage. Raillietinosis and davenportosis are natural focal tape helminthiases that parasitize in the small intestine of poultry. The research on chicken cestodiasis was carried out on poultry farms in the south of Odessa Region of Ukraine during 2017 and 2019. 4219 chickens of different age groups were examined, which used walking areas, with 1965 chickens – in 2017 and 2254 – in 2019. To assess the wet and dry periods with daily average temperatures above 10 °C, that is the period of active vegetation, the Selyaninov hydrothermal coefficient (SHC) was used (1937), according to which the spread of chicken cestodiasis was determined. In the south of Odessa Region, the moderate and severe period increased from four to seven months, at which the hydrothermal coefficient amounted to 0.4–0.5. The period of sufficient moisture at a hydrothermal coefficient of 1.0–1.5 decreased from three months of 2017 to two months of 2019 and the hydrothermal coefficient was not calculated for five and three months, respectively. In 2017, the hatching of cestode eggs with bird manure was recorded for nine months: from March (10.1%) to November (5.8%) with high rates in June (27.2%) and September (37.1%), while in 2019, cestode eggs were recorded in February (12.7%) and up to December (2.4%), that is, for 11 months, with the highest rates in May (41.8%) and September (43.9%). The species composition of chicken cestodes is represented by four species: Raillletina echinobothrida (74.2%), which dominates due to a longer low hydrothermal coefficient, as well as R. tetragona (9.8%), R. cesticillus (10.8%) and Davainea proglottina (5.2%). The invasion of ants with cysticeroid R. echinobothrida in 2017 amounted to 19.6%, and in 2019 – 25.9% with an intensity of 1 to 4 specimens.

The development of the poultry industry and the production of safe and high quality products are possible only with a stable epizootic situation concerning diseases of infectious and invasive etiology (Lorencena et al., 2018). It has been established that at industrial poultry enterprises in Ukraine, the most common ectoparasites are red chicken ticks (Dermanissus gallinae (De Geer, 1778)), also feather lice infest chickens and turkeys (Menopon gallinae (Linnaeus, 1758), Menacanthus stramineus (Nitzsch, 1818)) and the chicken tick is found on pigeons that live in homesteads. It has been proven that ectoparasites quickly spread when veterinary sanitary norms and rules are not followed and mechanical carriers are present (attendants, synanthropic birds, mice, etc.) and egg containers are used repeatedly without special treatment measures (Paliy et al., 2018).

Forest-Steppe of Ukraine, bird cestodiasis is registered, which most often...
is caused by raillietinosis and daveniosis (Bogach et al., 2019; Bogach & Stoyanova, 2020). Raillietinosis is a fairly common parasitic disease, but mainly in countries with a tropical and hotter climate (Sreedevi et al., 2016) on the Africa continent (Eshetu et al., 2001), India (Pulatalash-mannu et al., 2008), Jordan (Abdeljader et al., 2008), Iran (Radfar et al., 2012), Morocco (Hassouni & Belghiti, 2006). The ambient temperature and high precipitation in the Jammu region create favourable conditions for the more rapid development and spread of various stages of nematodes and cestodes (Katoch et al., 2012).

Most parasites in the process of individual development at a certain stage penetrate into the environment and lead an independent mode of life. At this time, they are represented as typical components of the biocenosis and are directly dependent on environmental conditions (Kashchira et al., 2018; Pally et al., 2018). The dynamics of the population of helminths depends on the characteristics of their life cycle and the way of circulation of biocenoses (Wells et al., 2018; Winter et al., 2018).

The biotic factors in spreading of disease include the pathogen, the area of its circulation in biocenoses, the peculiarities of biology and ways of influences of the farm. Among the abiotic causes, the most significant are meteorological factors: temperature, humidity, lighting, and precipitation, on which the maturation, viability, and distribution of eggs and larvae of helminths and intermediate parasite hosts depend (Fox et al., 2012; Blum & Hotez, 2018).

Since the middle of the 1980s in Odessa Region of Ukraine, deviations of certain weather factors from long-term average indicators have become significant, in particular, the number of warm winters has increased, and the average annual air temperature has increased by more than 3.5 °C and the reserve of productive moisture in the soil has decreased, which affects the increase of ant populations – intermediate hosts of Raillietina. Despite the fact that there have been reports from various parts of the world about the spread of parasites in poultry, it is still necessary to conduct parasitological studies in other parts of the country, taking into account changes in temperature and humidity.

According to Stepanenko (2007), after 2005 long dry and hot periods were recorded in the southern regions of Eastern Europe and the Mediterranean. The observed global warming significantly affects sectors that depend on climatic conditions, including agriculture (Mendelsohn, 2008; Gornall et al., 2010).

Data on the influence of hydrometeorological conditions on the spread of chicken raillietinosis has not been found in the literature and they are not accessible to us. In this regard, the aim of the work was to determine the indicators of the extensivity and intensity of chicken raillietinosis on farms in Odessa Region of Ukraine, taking into account the hydrometeorological conditions in 2017 and 2019.

Materials and methods

During 2017, 1965 chickens of different age groups which are kept on the floor were studied. In 2019, 2254 chickens were investigated with helminth coproscopic tests. During the parasitological examination of chickens, the indicators of the effect of the causative agents of cestodiasis – the extensivity (EI) and the intensity (II) of the invasion were determined and the number of eggs cestodes in 1 g of faecal was counted. For post-mortem diagnosis of cestodiasis, a small section of the intestine was taken from dead or killed chickens. The species of the detected helminth eggs was determined on the basis of morphological (colour, shape, size, number of shells) (Kapustin, 1953) and biological (degree of development of the embryo) features (Daxno & Daxno, 2010) and the existing description (Saif et al., 2008).

The invasion intensity was determined by the formula:

\[
EI = xy \times 100
\]

(1)

where EI – invasion extensivity, \(x\) – number of fecal samples in which the helminth eggs were found, \(y\) – total number of fecal samples, 100 – percentage conversion factor.

Data on the amount of precipitation and average air temperature are obtained from the Bolgrad meteorological station (Bolgrad, Odessa Region). The hydrothermal coefficient (HTC) of Selyaninov (1937) was used to assess the moisture conditions of a period with average daily temperatures above 10 °C, that is the period of active vegetation. In certain months of the year there are no active air temperatures above 10 °C, therefore, the HTC was not calculated. The hydrothermal coefficient (HTC) of Selyaninov was calculated by dividing the amount of precipitation (2R) in mm for a period with temperatures above 10 °C by the sum of active temperatures (2 act > 10) for the same period, reduced by 10 times:

\[
HTC = \frac{2R}{2 \text{ act} > 10} = \frac{2R}{2 \text{ act} > 10} - 10
\]

(2)

if HTC < 0.4 – very severe drought, HTC from 0.4 to 0.5 – severe drought, HTC from 0.6 to 0.7 – moderate drought, HTC from 0.8 to 0.9 – mild-drought, HTC from 1.0 to 1.5 – quite wet, HTC > 1.5 – excessively wet.

Results

During five months of 2017: January, February, March, November and December, the HTC ratio was not calculated due to the fact that the average daily temperature was below 10 °C (Table 1). For 4 months, HTC from 0.4 to 0.8 were recorded, indicating severe and moderate droughts.

| Months | Precipitation, mm | Average temperature, °C | Sum of active temperatures (\(\Sigma_{t > 10}\), °C) | HTC |
|--------|------------------|------------------------|---------------------------|-----|
| January | 27,9             | 12.2                   | 0                         | –   |
| February | 56,1             | 4,3                    | 0                         | –   |
| March   | 42.9             | 8,7                    | 0                         | –   |
| April   | 55.3             | 12.5                   | 375                       | 1.5 |
| May     | 52.4             | 17.2                   | 533                       | 1.0 |
| June    | 51.2             | 21.6                   | 648                       | 0.8 |
| July    | 34.7             | 24.7                   | 766                       | 0.5 |
| August  | 29.2             | 25.6                   | 794                       | 0.4 |
| September | 42.9             | 17.2                   | 516                       | 0.8 |
| October | 47.7             | 11.4                   | 353                       | 1.4 |
| November | 31.7             | 9.8                    | 0                         | –   |
| December | 50.3             | 1.2                    | 0                         | –   |

For three months, the moisture supply coefficient ranged from 1.0 to 1.5 and these months were characterized as sufficiently humid. For comparison, in 2019 the HTC ratio was not calculated only for three months: January, February, December (Table 2).

| Months | Precipitation, mm | Average temperature, °C | Sum of active temperatures (\(\Sigma_{t > 10}\), °C) | HTC |
|--------|------------------|------------------------|---------------------------|-----|
| January   | 32.2             | 22.2                   | 0                         | –   |
| February  | 42.4             | 9.7                    | 0                         | –   |
| March     | 31.2             | 11.4                   | 353                       | 0.9 |
| April     | 40.1             | 12.7                   | 381                       | 1.1 |
| May       | 29.9             | 19.6                   | 608                       | 0.5 |
| June      | 42.1             | 22.7                   | 681                       | 0.6 |
| July      | 39.2             | 25.5                   | 791                       | 0.5 |
| August    | 28.9             | 24.9                   | 772                       | 0.4 |
| September | 31.5             | 21.1                   | 633                       | 0.5 |
| October   | 29.1             | 14.2                   | 440                       | 0.7 |
| November  | 41.2             | 10.5                   | 315                       | 1.3 |
| December  | 49.8             | 3.4                    | 0                         | –   |

Severe and moderate droughts in 2019 were recorded for 7 months and only two months – April and November with a coefficient of HTC 1.1–1.3 were characterized as sufficiently wet. The HTC indicator affected the extensivity and intensity of cestodes in chickens. Among 1965 studied chickens, 329 (16.7%) were infested with cestodes (Table 3).

In January, February and December, cestode eggs were not found in poultry manure. In March, the HTC coefficient was 0 but among 79 studied chickens, only 8 (10.1%) had cestodiasis with an average intensity of 11.2 ± 2.1 eggs per 1 g of feces. At HTC 1.0–1.5 (sufficient wet) the extent of chicken cestodiasis was in the range of 22.6–30.1% with an average intensity of 18.4 ± 3.4 eggs in 1 g of feces. In 2019, 2254 chickens were studied, 629 (28.2%) were infested with cestodiasis (Table 4).

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In January 2019, among 76 studied chickens, cestodiasis was not registered in their eggs, while in 2017, such cestodiasis in eggs were not registered for three months: January, February, December. At HTC, 500 (36.8%) were affected by cestodiasis.

Table 3

| Months  | HTC | Studied heads | Infested heads | EL, % | II. eggs in 1 g of feces |
|---------|-----|---------------|----------------|-------|-------------------------|
| January | –   | 117           | –              | –     | –                       |
| February| –   | 198           | –              | –     | –                       |
| March   | –   | 79            | 8              | 10.1  | 11.2 ± 2.1              |
| April   | 1.5 | 124           | 28             | 22.6  | 13.1 ± 0.8              |
| May     | 1.0 | 170           | 42             | 24.7  | 19.9 ± 1.1              |
| June    | 0.8 | 168           | 34             | 20.2  | 22.1 ± 3.4              |
| July    | 0.5 | 181           | 31             | 17.1  | 17.6 ± 0.9              |
| August  | 0.4 | 96            | 16             | 16.7  | 20.2 ± 1.2              |
| September | 0.8 | 245           | 91             | 37.1  | 29.6 ± 0.5              |
| October | 1.4 | 209           | 63             | 30.1  | 22.4 ± 2.2              |
| November| –   | 275           | 16             | 5.8   | 7.2 ± 0.8               |
| December| –   | 103           | –              | –     | –                       |
| Total   | –   | 1965          | 329            | 16.7  | –                       |

Table 4

| Months  | HTC | Studied heads | Infested heads | EL, % | II. eggs in 1 g of feces |
|---------|-----|---------------|----------------|-------|-------------------------|
| January | –   | 76            | –              | –     | –                       |
| February| –   | 204           | 26             | 12.7  | 5.6 ± 1.0               |
| March   | 0.9 | 205           | 29             | 27.6  | 12.9 ± 2.1              |
| April   | 1.1 | 99            | 34             | 34.3  | 17.7 ± 0.6              |
| May     | 0.5 | 244           | 102            | 41.8  | 28.2 ± 2.4              |
| June    | 0.6 | 201           | 81             | 40.2  | 22.5 ± 1.5              |
| July    | 0.5 | 175           | 36             | 32.0  | 24.4 ± 0.9              |
| August  | 0.4 | 124           | 36             | 29.0  | 18.6 ± 1.3              |
| September | 0.5 | 207          | 91             | 43.9  | 21.2 ± 2.7              |
| October | 0.7 | 302           | 105            | 34.7  | 26.5 ± 1.4              |
| November| 1.3 | 311           | 64             | 20.5  | 18.1 ± 0.5              |
| December| 1.6 | 206           | 5              | 2.4   | 7.2 ± 0.2               |
| Total   | –   | 2254          | 629            | 28.2  | –                       |

In January 2019, among 76 studied chickens, cestodiasis was not registered in their eggs, while in 2017, such cestodiasis in eggs were not registered for three months: January, February, December. At HTC 1.1–1.3 among 410 studied chickens, 98 (23.9%) were affected by cestodiasis. In the case of HTC from 0.4 to 0.9 among 1358 studied chickens, 500 (36.8%) were affected by cestodiasis.

The nature of hydrometeorological conditions, moving in the direction of warming and severe and moderate droughts directly affects the increase of extensivity of raiillietinosis in chickens. In 2017, 107 ants were studied by the compressor method, 21 (19.6%) ants were infested with cysticercoids Raillietina echinobothrida with an intensity of 1 to 3 (Fig. 1). In 2019, among 116 studied ants, 30 (25.9%) were infested with an intensity of 1 to 4.

Table 5

| Species composition of cestodes of chickens in 2017 on farms in the south of Odessa Region |
|----------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                       | HTC Duration    | Total amount of infested heads | Raillietina echinobothrida | R. tetragona | R. cesticillus | Davainea proglottina |
|                                       |                 |                               |                              |               |                |                              |
|                                       |                 | 0.4–0.8 4 months             | 172                          | 109             | 21             | 24             | 18 |
|                                       |                 | 1.0–1.5 3 months             | 133                          | 22              | 40             | 39             | 32 |

According to the results of our research in mild and moderate droughts, which lasted 4 months, R. echinobothrida dominates (63.4%). The infestation of chickens with R. tetragona was 12.2%, R. cesticillus – 13.9% and D. proglottina – 10.5%, which is 80.7%, 78.1% and 83.4% less compared to R. echinobothrida. In the wet period, which lasted 3 months, R. tetragona (30.1%), R. cesticillus (29.3%) and D. proglottina (24.1%) dominated, due to the presence of a large number of beetles (intermediate hosts) and R. echinobothrida was recorded in chickens (16.5%).

During the long dry period which lasted 7 months in 2019, R. echinobothrida (74.2%) dominated among the chicken cestodes, which is 14.6% more than in the same period in 2017 (Table 6).

Table 6

| Species composition of cestodes of chickens in 2019 on farms in the south of Odessa Region |
|----------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                       | HTC Duration    | Total amount of infested heads | Raillietina echinobothrida | R. tetragona | R. cesticillus | Davainea proglottina |
|                                       |                 |                               |                              |               |                |                              |
|                                       |                 | 0.4–0.8 7 months             | 500                          | 371             | 49             | 54             | 26 |
|                                       |                 | 1.0–1.5 2 months             | 98                            | 13              | 38             | 27             | 20 |

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The nature of hydrometeorological conditions, moving in the direction of warming and severe and moderate droughts directly affects the increase of extensivity of raiillietinosis in chickens. In 2017, 107 ants were studied by the compressor method, 21 (19.6%) ants were infested with cysticercoids Raillietina echinobothrida with an intensity of 1 to 3 (Fig. 1). In 2019, among 116 studied ants, 30 (25.9%) were infested with an intensity of 1 to 4.

**Discussion**

The territory of the southern districts of Odessa Oblast is located in the southwestern part of the Steppe agro climatic zone of Ukraine. According to the regional agrochemical laboratory, the structural composition of the southern black soils is characterized by insignificant dispersion of the upper soil layer, and the lower ones have a granular structure. The physical condition of soils and the physical processes that occur in them is one of the most important indicators that contribute to the growth of the interme-
diate host population – ants and determine the preservation of the viability of helmint eggs. It has been established that the distribution and intensity of tapeworms is quite high in conditions of intensive chicken rearing and they are transmitted by various species of invertebrate hosts through bird droppings (Harrilishishan & Ponnduradu, 2010).

Precipitation is one of the most unstable elements of the climate and, at the same time, its quantity and seasonal distribution in Southern Ukraine are of particular importance in relation to the spread of bird helminthiasis. Differences in the spread of parasitic infection can be caused by differences in the climatic conditions of the region, the presence of intermediate hosts, or the way chickens are kept, as previously stated (Hange et al., 2007; Percy et al., 2012).

Magwisha et al. (2002) reported that climatic conditions (temperature and humidity) can change the population dynamics of parasites, which leads to changes in the spread and intensity of helmint infections in general. Among the factors restraining the development of young birds and the productivity of adult birds are invasive diseases, in particular cestodiosis. Poultry cestodiasis are quite common throughout the world, mostly in the countries with a hot and temperate warm climate (Kurt et al., 2008; Huussen et al., 2012). Under the ecogeographic conditions of the South of Ukraine, the distribution, seasonal, and age-related dynamics of bird cestodiosis are influenced by complex phenomena due to the wide influence of abiotic and biotic environmental factors. Among them, climatic factors are of great importance and, first of all, changes in the nature of nutrition and lifestyle of the hosts, ecology and development cycles of intermediate hosts of Raillietina and Davaineia cestodes (entomophagous ants Tetratomorium caespitum (Fornicidae), beetles – ground beetles Opatrodes frater (Coleoptera)), Anoplocephala (earthworms Eisenia fetida, Lumbricidae), Muscidae (housefly Musca domestica L.), which affect the possibility and probability of infection of the birds with cestodes (Bogach et al., 2013).

Differences in the spread of parasitic diseases can be caused by specific various climatic conditions of the region, the presence of intermediate hosts, or the way in which birds are kept (Magwisha et al., 2002; Hange et al., 2007; Percy et al., 2012). This is also confirmed by our data – in the southern districts of Odessa Region in Ukraine, the distribution of chicken cestodiasis depends on the hydrothermal coefficient and, accordingly, the growth of population of Fornica ants.

Significant correlation between seasonality and the spread of gastrointestinal parasites was observed in the Gunnuravam area, Andhra Pradesh and its environs. The data indicated their high prevalence during the rainy season (43.4%), followed by the summer (38.9%) and winter (17.1%) periods (Sreedevi et al., 2016). The ambient temperature and high rainfall in the Jammu region contribute to the more rapid development and spread of various stages of bird nematodes and cestodes (Katoch et al., 2012).

In domestic chickens from Tanzania during the wet and dry periods, the presence of R. echinobothrida (41.3% and 46.3%, respectively), R. tetragona (25.3% and 21.3%, respectively), R. cesticillus (8.7% and 2.7%, respectively) were registered (Parmian et al., 1997).

In the period from March 2005 to August 2006, a study was conducted to identify and evaluate the spread of parasites of local chickens in the semi-arid region of Kenya. Thus, R. echinobothrida (33.3%) and D. proglottina (19.4%) were the two most important types of cestodes (Mungubue et al., 2008). So, our results supplement the data on the distribution of birds’ cestodiasis, which is confirmed by the results of other researchers from other countries around the world.

There are scant but interesting data concerning poultry infection with helminths in the region of Aswan province, Upper Egypt. From April 2016 to March 2017, 276 birds were examined (156 chickens and 120 domestic pigeons). The study showed that the overall prevalence of parasitic diseases was 55.8% (154/276). In addition, 59.1% of the chickens had mixed infections with four cestode and three nematode species. Among the cestodes, the most common species were R. tetragona (16.0%), followed by R. echinobothrida (11.0%), Cotugnia digonopora (6.4%) and R. cesticillus (1.3%). Meanwhile the highest rates of infection were found in summer and the lowest were recorded in winter (El-Dakhly et al., 2019).

A significant difference was found between the distribution of helminths in different agroecological zones of Ethiopia. The highest prevalence was observed in lowland areas. This suggests that agro ecology has a great influence on the spread of parasites. The main types of cestodes were R. echinobothrida (25.8%), R. tetragona (45.7%), R. cesticillus (5.6%), Anoplocephala sphenoides (40.5%) and D. proglottina (1.1%) (Eshetu et al., 2001).

The high prevalence of cestodiasis in domestic chickens can be explained by the fact that chickens were kept on a livestock pasture and had access to invasion of the environment and intermediate hosts such as ants, beetles, earthworms, etc. Thus, the study of the seasonal dynamics of chicken raiilnitotnosis is of great importance for determining the sources of invasion, as well as to carry out the deworming on time. To know the peak of invasion allows one to develop a scheme for deworming of poultry, which will be relevant for this region and differ from the generally accepted time.

Conclusion

According to the hydrothermal coefficient in the south of Odessa Region of Ukraine, moderate and severe periods of drought have increased from 4 to 7 months, which affects the increase in the population of intermediate hosts of chicken cestodiasis – ants belonging to the genus Formica. In 2017, the isolation of cestode eggs from bird droppings was recorded from March to November with an intensity of 5.8% to 37.1% with the highest rates in June (27.2%) and September (37.1%), whereas in 2019, cestode eggs were recorded from February to December (from 12.7% to 2.4%), with high rates in May (41.8%) and September (43.9%). The species composition of chicken cestodes is represented by four species: R. echinobothrida (74.2%), which dominates due to the longer low HTC, as well as R. tetragona (9.8%), R. cesticillus (10.8%) and D. proglottina (5.2%).

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