

INFLUENCE OF ABIOTIC STRESS FACTORS ON BLACKCURRANT RESISTANCE TO PESTS

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ABSTRACT: Blackcurrant is one of the most valuable berries in a temperate zone. *Lampronia capitella Cl.* is an extremely dangerous pest of blackcurrant in the South Ural region. Abiotic stress factors can significantly reduce blackcurrant resistance to *L. capitella Cl.* We studied blackcurrant in two areas and in a laboratory. The first area is situated close to a residential area, and a busy motorway is just 100 m from this station. The second area consists of 5 private household plots in an environmentally clean area, far from the city and motorways. We noted that, in the horticultural selection station, *L. capitella Cl.* population explosion was often three times more than in the household plots. We compared the growth of *L. capitella Cl.* larvae in nature and in the laboratory at different temperatures. The experiment lasted for 7 days at +25 °C in the laboratory, and for more than 13 days at daily average temperatures of +9.7 °... +15.1 °C in private household plots. We discovered that the larvae's harmfulness increases at temperatures less than +25 °C. Under the influence of anthropogenic stress coefficient of assimilated food was higher than in clean areas because there is the low immunity of blackcurrant in adverse environmental conditions.

Keywords: Blackcurrant, *Lampronia Capitella Cl.*, Resistance to Pest, Abiotic Stress, Coefficient of Assimilated Food

1. INTRODUCTION

Blackcurrant is rich in vitamins and bioactive substances [1]–[4]. It is one of the most valuable berries of temperate zones. Blackcurrants are an important berry crop in many European countries [5]. There is increasing demand for new and economically valuable blackcurrant cultivars suitable for organic production. In recent years, there have been significant changes in the methods of berry crops in some parts of Europe. Now, most blackcurrants are concentrated in central, east, and south-eastern Europe where the growing method relies on “traditional” open-field production systems [5].

Blackcurrant are attacked by a wide range of insect and mite pests that can reduce the quality and yield or have phytosanitary implications in propagation and plant exports. Many of the insects and mites colonise small fruits specific to them. So, specific insect control strategies must be developed [5]. To date, research into blackcurrant insect pests has been fragmented, with little appreciation of how changes in climate and agronomic practices affect biology. It is very important to concentrate on enhancing natural plant resistance to some important pests and diseases.

Lampronia capitella Cl. is an extremely dangerous pest of blackcurrant in the South Ural region. Predicting how insect crop pests will respond to global climate change is an important part of increasing crop production for future food

security [6]. It has been shown [7] that global climate change can accelerate the breakdown of crop resistance to insect pests. It is anticipated that global climate change could lead to increase in the incidence of blackcurrant through the increased overwintering survival and longer seasonal activity of *L. capitella Cl.*

There are scientific studies that allow us to evaluate varieties of black currant in respect to their yield, the quality of berries, and resistance to pests [8]. Moreover, changes in management practices such as increased cropping densities and machine harvesting could lead to pest outbreaks through optimal microhabitats and increased susceptibility to pest colonization. It is important to consider future management options with an emphasis on integrated approaches to pest management, including biocontrol and plant resistance enhancement through breeding [9].

The natural environment for plants consists of a complex set of abiotic and biotic stresses. Plant responses to these stresses are complex. While it is difficult to get accurate estimates of the effects of abiotic stress on crop production, it is evident that abiotic stress continues to have a significant impact on plants [10], [11]. The level and duration of stress (acute vs chronic) can have a significant effect on the complexity of the plants response [12], [13].

Abiotic stress is defined as environmental conditions that reduce growth and yield below optimum levels [14], [15]. With long-term stress,

photosynthesis declines due to stomatal limitations for CO₂ uptake and increased photoinhibition from difficulties in dissipating excess light energy [13] Abiotic stress factors can significantly reduce blackcurrant resistance to *L. capitella Cl.* There are only a few very old publications on blackcurrant pest *L. capitella Cl.*

The aim of this paper was to investigate the influence of abiotic stress on the resistance of blackcurrant to the pest *L. capitella Cl.*

2. METHODS

2.1 The Conditions of Blackcurrant Cultivation

In the research for this article, the blackcurrant were grown in 2015 under three conditions: (1) laboratory, (2) natural conditions, Area 1, (3) natural conditions, Area 2 (Fig. 1).

RF-grown blackcurrant cultivar ‘Desertnaya’ was used for each experiment. Bushes were grown under standard field conditions.



Fig. 1 Study area

Area 1 is situated close to the residential area, and a busy motorway is just 100 m from the site (Fig. 2).



Fig. 2 The blackcurrant is grown in Area 1

Area 2 consists of 5 private household plots in

an environmentally clean area far from the city and motorways (Fig. 3).



Fig. 3 The blackcurrant is grown in Area 2

2.2 Examining the Growth of *L. Capitella Cl.* Larvae

We compared the growth of larvae: (1) in nature and (2) in the laboratory at different temperatures.

In nature we studied the growth of the larvae. We made 5 frameless mesh cages-isolators on a blackcurrant branch which contained some of the buds. We placed 2 larvae in each mesh cage-insulator (in total, there are 10 larvae). The mesh cage did not allow the larvae to spread, but larvae could move from the bud to the bud. The larvae took more than 13 days in natural conditions in average daily temperatures of +9.7... +15.1 °C. The air temperatures were monitored and recorded each hour during the same period by air temperature sensors

The larvae were weighed when they left the buds, and therefore at the air temperature of +9.7 °C in natural conditions, the second larval instars were weighed twice, not once, for the first two days of their development. When weighing the larvae, the biology of *L. capitella Cl.* was experimentally confirmed and taken into account.

In the laboratory, we used 5 Petri dishes for each, and 2 larvae per Petri dishes (a total 10 larvae). The laboratory experiment was conducted for seven days at an air temperature of +25 °C, air humidity of 70–75 %, with ten hours of daylight. Thermostat was used to maintain temperature.

2.3 Food Assimilation by *L. Capitella Cl.* Larvae

L. capitella Cl. larvae have 4 instars. According to the conventional approach, the number of instars is equal to the number of molts. The experiment did not consider the first larval instars as they fed on the berries, and they have a direct impact on the black currant crop. For the second, third, and fourth instar larvae we studied food assimilation. We weighed the original amount of food, the remaining amount of food, and

excrement. The coefficient of food assimilation, C was calculated according to the equation:

$$C = \frac{(M_f - M_e)}{M_f} \cdot 100\%,$$

where M_e – larva excrement mass (mg) and M_f – mass of food eaten (mg).

Microsoft Excel 2013 and SPSS 24.0 software were used to organize and analyze the data. Differences in the coefficients of food assimilation were analyzed using ANOVA with post-hoc comparisons made using Fisher's least significant difference (LSD).

3. RESULTS AND DISCUSSION

The results of five years of research showed that the population of *L. capitella Cl.* increases faster in Area 1 (the horticultural breeding stations), where blackcurrant is a monoculture and grows under the influence of abiotic stress. In laboratory conditions, populations of *L. capitella Cl.* behave the same. This is because in the laboratory population of *L. capitella Cl.* currant with reduced defense mechanisms remained on injured branches. In Area 2 (private farms) the number and activity of the pests were much smaller than in Area 1, in conjunction with other types of plants. It is located in an ecologically clean area far away from cities and highways.

Insects are poikilothermal with their body temperature depending on that of the surroundings. Insect activity rhythm is directly connected to changes in the surroundings [16]. Their rhythm of life can differ in different points within the same space, since they can differ in microclimatic conditions [17], [18]. For instance, temperature change influences the feeding intensity of insects including *Lampronia capitella Cl.* Further, feeding intensity should be researched to give a more detailed analysis of *L. capitella Cl.* harmfulness in various surroundings.

Basing upon the classification of insects according to their activity rhythm given by [19], *Lampronia capitella Cl.*, according to our data, can refer to the insects whose feeding habits are equally intensive throughout the day. This is primarily due to the fact that *L. capitella Cl.* develops in food abundance (in the food substratum: bud or berry) (Fig. 4, 5).

L. capitella Cl. nutritional adaptation is very important for identifying the researched characteristics. Numerous studies have shown that insect voracity depends directly on the physiological state of the forage plant [20].

The experiment revealed that in laboratory conditions the amount of food eaten by the larvae

for the whole process of their development, i.e. of the second, third, and fourth instars, was 60.44 mg. In natural conditions with an average temperature of +12.4 °C, the amount was 94.4 mg, which is 1.6 times more than in the laboratory.



Fig. 4 *L. capitella Cl.* on blackcurrant



Fig. 5 Appearance *L. capitella Cl.*

Studying feeding intensity of the second, third and fourth larval instars separately, the fourth instars are revealed to be the most active, and therefore they are more harmful than the second and third larval instars.

We understand that uredospores, as an indicator of yield reduction per plant, are influenced by the life of one individual pest [21]. The mass of food eaten by the second instar larvae was 11.8 mg for the entire period of their development under laboratory conditions when the air temperature was +25 °C. The weight of food eaten by the fourth instar larvae was 28.96 mg, 2.5 times more than in the laboratory. Similar patterns were observed in natural conditions. For example, in natural conditions over the period of full development, the second and fourth instars larvae destroyed 21.7 mg and 39.84 mg food, respectively. The third instars of *L. capitella Cl.* consumed 19.68 mg of food in the laboratory. In contrast, in natural conditions, this value was 33.86 mg when the air temperature was +13.9 °C.

The voracity coefficient for the fourth larval instars was discovered to be 34.5 %; for the third –

25.4 %; and for the second – 12.7 %. These findings suggest that the fourth larval instars are the most voracious. Table 1 illustrates larval voracity according to their instars in the natural and laboratory conditions.

Table 1 Mass of food eaten by *L. capitella Cl.* during their development

Larvae age	M _f , mg	M _e , mg	C, %
Laboratory			
II	11.80±0.01	7.06±0.01	40.2±0.1
III	19.68±0.02	11.26±0.02	42.8±0.3
IV	28.96±0.03	17.44±0.03	39.8±0.1
Total	60.44±0.02	35.76±0.02	40.8±0.2
Nature (Area 1)			
II	20.7±0.01	12.29±0.01	40.6±0.1
III	33.86±0.03	20.53±0.02	39.4±0.2
IV	39.84±0.03	27.13±0.03	31.9±0.02
Total	94.40±0.02	59.95±0.02	36.5±0.02
Nature (Area 2)			
II	32.71±0.01	22.29±0.01	31.9±0.1
III	45.76±0.03	31.43±0.02	31.1±0.1
IV	51.48±0.03	37.13±0.03	27.9±0.2
Total	129.90±0.02	90.85±0.02	30.1±0.01

Thus, at an air temperature of +25 °C, the second larval instars ate 7 mg of food on average, while in natural conditions larvae of the same instars ate 5.7 mg of food daily. At an air temperature of +25 °C, the third instars ate 10.52 mg of buds, while at in natural conditions the amount of food eaten was 9.5 mg. The fourth larval instars ate 13 mg of food at +25 °C, while in natural conditions the mass of food eaten daily was 10.2 mg of buds.

When studying the dynamics of the digestion coefficient, it was noted that in the laboratory conditions at an air temperature of +25 °C, air humidity of 70–75 %, and 10 hour daylight, the digestion coefficient slightly changed with age, accounting for 40.2 % for the second instars, 42.8 % for the third, and 39.8 % for the fourth. In natural conditions at the average air temperature from 9.7 °C to 15.1 °C of the digestion coefficient declined from the second larval instars to the fourth, being 40.6 %, 39.4 %, and 31.9 % respectively (Table 1). These results indicate that the second larval instars digest food better.

Study of the food chains, voracity, and harmfulness of *L. capitella Cl.* instars showed that the most voracious are the fourth larval instars for which the voracity coefficient is 34.5 %, while the second instars are less voracious (12.7 %). But the digestion coefficient for the fourth instars is the lowest (31.9 %). The lower the air temperature is, the worse the larvae digest food.

From the data in Table 1 it can be seen that in Area 2, Area 1 and in laboratory the totals of food assimilation were 30.1, 36.5 and 40.8, respectively. These values are statistically significantly different according to ANOVA test ($p=0.95$). Thus, in the laboratory the coefficient of larval assimilated food was higher than in natural conditions. The reason of or this is that at the temperature of +25 °C (the laboratory experiment) the life cycle of larvae was shorter than in natural conditions at daily average temperatures of +9.7 °... +15.1 °C.

On the whole, the digestion coefficient of larvae brought up in the permanent laboratory conditions is higher (40.8 %) than that of those grown in varying natural conditions (36.5 %). Moreover, the digestion coefficient increases with age for the larvae grown in the laboratory conditions. In natural conditions, the coefficient declines with age. This means that at the air temperature of +25 °C, nutrients are better digested and, consequently, the development cycle extends and the harmfulness of *L. capitella Cl.* grows (Fig. 6). Table 1 present how the digestion coefficient changes for the second, third, and fourth instars during their development.



Fig. 6 Butterfly *L. capitella Cl.* in the period of egg laying

In natural conditions, the coefficient of assimilated food was a less than in the laboratory. And therefore, the number of damaged buds was a higher than in the laboratory. Under the influence of anthropogenic stress (Area 1) coefficient of assimilated food was higher than in clean areas (Area 2). This is a consequence of the low immunity of plants (blackcurrant) in adverse environmental conditions.

Comparison of the conditions of blackcurrant cultivation showed that the population of *L. capitella Cl.* increased faster in Area 1 (breeding stations), where the blackcurrants are growing under the influence of abiotic stress. In the

laboratory, the population of *L. capitella Cl.* was the same. In Area 2 (private farms), the number and activity of the pest was much smaller than in Area 1.

Food assimilation by *L. capitella Cl.* larvae was higher for larvae in constant laboratory conditions than larvae in changing natural conditions. The larvae's harmfulness increases at temperatures less than +25 °C.

4. CONCLUSION

In natural conditions, coefficients of assimilated food were (30.1±0.2) % and (36.5±0.2) % for clean and anthropogenically polluted areas, respectively/ It is a less than in the laboratory – (40.8±0.2)%. And therefore, the number of damaged buds was a higher in the nature than in the laboratory. Under the influence of anthropogenic stress (Area 1) coefficient of assimilated food was higher than in clean areas (Area 2). This is a consequence of the low immunity of plants (blackcurrant) in adverse environmental conditions.

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