

Research Article

The Influence of Host Plants on Herbivore Community Composition on *Brassica* Crops in Western Siberia

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Experiments on three varieties of *Brassica oleracea* (white cabbage, red cabbage, and cauliflower) were conducted during the years 2008–2011 in Western Siberia (Russia) to study the influence of host plant on herbivore infestation. The results revealed the evidence of different infestation of white cabbage, red cabbage, and cauliflower by the common herbivores in Western Siberia. Flea beetles as the earliest herbivores preferred to infest white cabbage. Contrary to those herbivores, *M. brassicae* and *P. xylostella* larvae infested red cabbage most of all. The latest herbivore of all plants studied, *P. brassicae*, preferred cauliflower but not red cabbage. The possible contribution of some factors in summary effects observed in the study was discussed. Further studies are being planned in which tritrophic interaction including *B. oleracea* plant, herbivore, and microbial insecticides should be investigated. These studies will help to develop biological insect control on *Brassica oleracea* crops in order to supply ecologically safe plant protection.

1. Introduction

Plants of *Brassicaceae* family include worldwide commercially grown crops. Among these plants, white cabbage (*Brassica oleracea* L. var. *capitata*) is the most common vegetable crop grown in regions with cold continental climate, and Western Siberia (Russia) is one of such regions. Due to specific biological properties, the cabbage is able to finish development during a short vegetative period. Recently, in Western Siberia, together with white cabbage, other *Brassica* varieties have been cultivated including cauliflower (*Brassica oleracea* L. var. *botrytis*) and red cabbage (*Brassica oleracea* L. var. *rubra*). The cauliflower contains more protein, potassium, phosphorus, and some vitamins compared with white cabbage [1]. Red cabbage differs from other varieties in high content of anthocyanins useful for people health [2].

In Western Siberia, *Brassica* plants are seriously attacked by herbivores during vegetative period [3]. After planting to crop harvesting, flea beetles, cabbage moth, diamondback moth, white butterfly, and other herbivores infest plants and could dramatically decrease the yield without insecticides

treatment. However, the preference should be done to biological insecticides because fruits of *Brassica* plants are often consumed as fresh product. In Western Siberia, biological insect control has been developed on white cabbage [4]. For development of such environmentally friendly pest control on other varieties of *Brassica oleracea* in this region, the initial research on host plant-herbivore interaction is necessary. The significance of the problem of *Brassica* host plant response to herbivore infestation has been shown by several authors [5–7]. These data together with the publications on plant-insect interactions as a whole [8, 9] pointed out the complexity of the problem mentioned above. The plant response to herbivore attack is determined by the relative contribution of constitutive and inducible plant resistance to insects [10]. In addition, plant resistance to herbivorous insects depends on some traits including plant morphology, physical barriers, composition of primary and secondary metabolites, plant age, and even geographical latitude [11–14]. For plants of *Brassicaceae* family (cabbage, cauliflower, and others), glucosinolates content and its hydrolysis products by myrosinase including isothiocyanates play a prominent role in plant

resistance to herbivores [15]. It is important, however, that the total plant response to insect attack is determined not by a single trait but by the so-called syndrome [16, 17]. Moreover, the trait variation could be dependent both on gene expression and on environment [18, 19]. From our opinion, for the purpose of the studying plant-insect interaction as a basis of microbial insect control, a summary response of host plant to insect attack expressed as the insect infestation depending on plant age and weather condition should be the most adequate response. Therefore, the aim of this research is the influence of host plant on insect infestation of three *Brassica oleracea* varieties and the data analysis according to factors mentioned above.

2. Materials and Methods

2.1. Plant Growth. Seeds of white cabbage, red cabbage, and cauliflower were sown simultaneously. The plants were growing in a greenhouse from the end of April to June. At the beginning of June, seedlings were transplanted into the field site.

2.2. Field Site. A field experiment was conducted during the years 2008–2011 near Novosibirsk, Russia. The experiments were carried out in three variants, and each variant was in four replications. Twelve plots (20 m²) including three plant varieties were established using a randomized design. Each plot contained 25 plants.

2.3. Herbivore Biodiversity Calculations and Analysis. The number of individuals of herbivore species was counted on the 25 plants of a plot once in 7–10 days during all the vegetative period. These values were used to calculate the total herbivore abundance per 100 plants.

2.4. Laboratory Experiments. *Mamestra brassicae* L. and *Pieris brassicae* L. larvae were reared in laboratory on three different varieties of plants from hatch to pupation. Larvae were placed in Petri dishes (10 individuals in each dish). After pupation, the weight of every pupa was detected.

2.5. Statistical Analysis. The data obtained from field and laboratory observations were subjected to an analysis of variance using Statistica 6.0 (Statsoft, Tulsa, OK), and the LSD test ($P \leq 0.05$) procedure was applied. The figures are performed by the Microsoft Excel software (Microsoft Corporation, Roselle, IL, USA).

3. Results

3.1. Weather Conditions. Data on weather conditions in the period 2008–2011 are presented in Table 1.

3.2. Flea Beetles Infestation. Flea beetles *Phyllotreta* spp. are the first herbivore appeared on all host plants studied in this research. In Western Siberia, the beetles are the most harmful herbivores in early season during 3–4 weeks after *B. oleracea* planting (June). In the period of 2008–2011, the herbivore

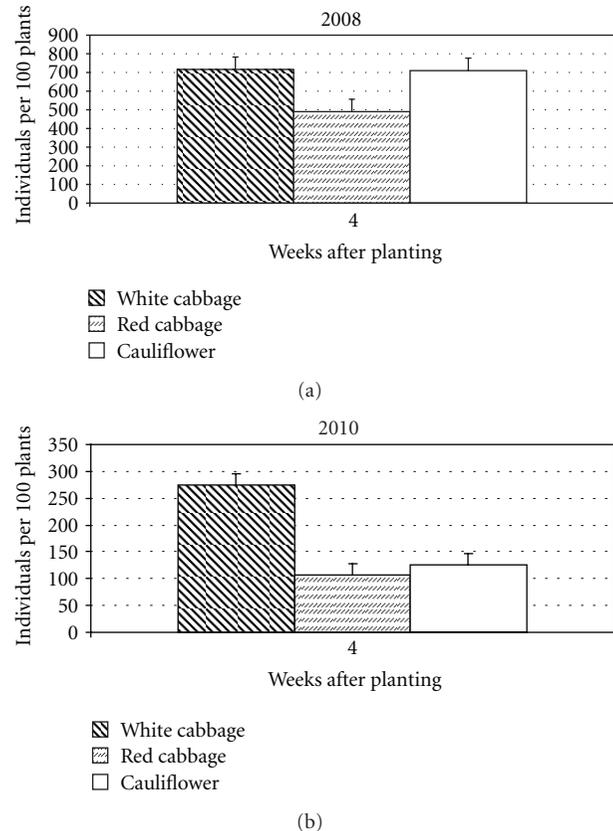


FIGURE 1: Number of flea beetles infested white cabbage, red cabbage, and cauliflower: (a) in 2008, (b) in 2010.

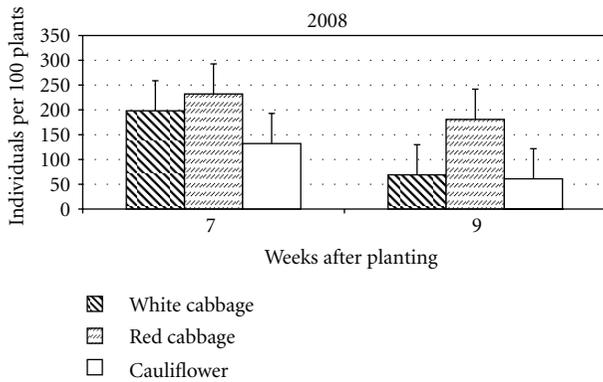
abundance varied depending on weather conditions and *Brassica oleracea* varieties. We observed heavy pest infestation of crops in 2008. Later, the infestation was significantly less (2009–2010), and in 2011, only single beetles were discovered. The highest insect abundance was observed in plant age of 7–9 leaves (4 weeks after planting). The flea beetles preferred to infest white and red cabbage compared with cauliflower, and this preference increased at lower number of individuals per plant (Figure 1).

3.3. Plant Infestation by Cabbage Moth. *Mamestra brassicae* is the most harmful pest insect of *Brassica* plants in the region. In 2008, we observed the highest level of the herbivore performance on host plants. Contrary to flea beetles, *M. brassicae* caterpillars preferred to infest red cabbage. In 9 weeks after planting when plants started to form heads, the number of herbivores reached 2.3 individuals per plant.

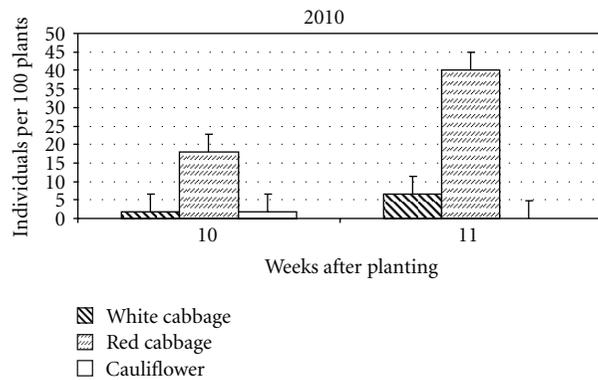
The infestation of white cabbage and cauliflower by caterpillars was lesser especially on the latter (1.3 individuals per plant) (Figure 2(a)). In 2009, *M. brassicae* larvae were observed only as single one, and there was no difference in their performance on three plant varieties. In 2010, the number of individuals per plant significantly decreased, and larvae appeared later in the season (Figure 2(b)). However, the most preferable host plant was the red cabbage like in 2008. In 11 weeks after planting, we observed 8 times more

TABLE 1: Temperature and rainfall in vegetative seasons of 2008–2011 in the field sites.

Month	2008		2009		2010		2011	
	t°, C	Rainfall, mm						
June	17, 5	54	13, 8	70	17, 2	37	20, 1	30
July	20, 5	35	18, 6	95	17, 4	79	17, 1	44
August	16, 4	53	16, 4	42	17, 1	25	15, 4	50
September	8, 8	43	10, 8	23	10, 7	57	11, 3	14



(a)



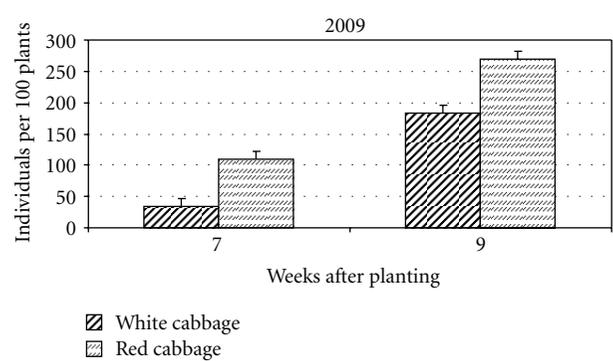
(b)

FIGURE 2: Number of *M. brassicae* larvae infested white cabbage, red cabbage, and cauliflower: (a) in 2008, (b) in 2010.

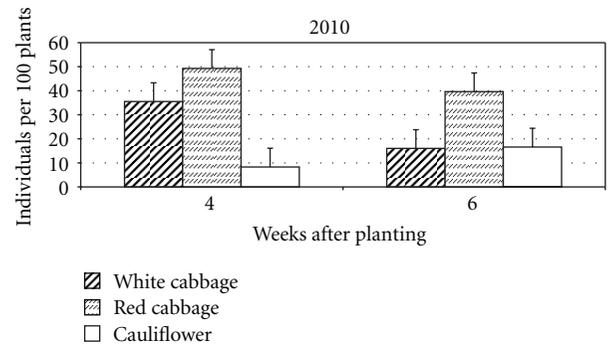
individuals on red cabbage compared with white cabbage, and no infestation of cauliflower was registered. In 2011, *M. brassicae* preferred to infest the red cabbage as well (data are not presented).

3.4. Plant Infestation by *Plutella xylostella* L. The infestation of *Brassica oleracea* crops by diamondback moth *P. xylostella* in 2009 was significantly more than in 2010 (in 2009, planting of cauliflower was not performed) (Figure 3). Both in 2009 and 2010, the preferable host plant appeared to be the red cabbage. In 2010, cauliflower was infested significantly lower than two other plant varieties in 4 weeks after planting; however, in 6 weeks after planting, the level of herbivore infestation was similar on white cabbage and cauliflower.

3.5. Plant Infestation by *Pieris brassicae* L. High level of three host plants infestation by white butterfly *P. brassicae* was



(a)



(b)

FIGURE 3: Number of *P. xylostella* larvae infested white cabbage, red cabbage, and cauliflower: (a) in 2009, (b) in 2010.

observed only in 2009. The first insect appearance was noticed 11 weeks after planting (August), and the infestation was continued to yield formation. The highest level of infestation was registered on cauliflower, the abundance of caterpillars was 2–2.5 times lesser, and no infestation was demonstrated on the red cabbage (Figure 4). This situation did not depend on plant age.

Due to field observation of *P. brassicae* during only one vegetative season, we carried out the experiment in laboratory to reveal longevity of larval development and pupae survival and weight (Table 2). The shortening of larval stage was noticed on cauliflower. The red cabbage was the most unfavorable for *P. brassicae* under laboratory conditions. The longest larvae development together with the least percent of survived pupae and the lowest pupae weight have been registered for herbivorous insects reared on the red cabbage.

TABLE 2: Parameters of *Pieris brassicae* development on *Brassica oleracea* under laboratory condition.

<i>B. oleracea</i> variety	Longevity of larval development, days ($\bar{x} \pm S_x$)	Survived pupae, %	Pupae weight, mg ($\bar{x} \pm t_{05} \times S_x$)
White cabbage	17,4 ± 0,3	59,6	319,7 ± 11,6
Red cabbage	18,6 ± 0,2	50,7	272,8 ± 13,4
Cauliflower	15,1 ± 0,4	78,3	303,7 ± 8,2
LSD ₀₁		11,4	—

4. Discussion

The results obtained here testified that varieties of *B. oleracea* influence the infestation of host plants by herbivores in field. The appearance and development of four herbivorous insects in 2008–2011 depended on weather conditions. Namely, season of 2008 was favorable for flea beetles and cabbage moth, 2009 for diamondback moth and white butterfly, 2010 for flea beetles and cabbage moth, and in 2011, only *M. brassicae* infestation was observed. Among herbivores, only *M. brassicae* is generalist, and others are specialists. We registered the total response of host plant to insect attack expressed as herbivore abundance on each *B. oleracea* variety. However, it is necessary to consider these results from the standpoint of known mechanisms of plant-insect interaction. This includes host plant age, morphological and physical properties of the plant, the role of plant secondary metabolites, and others.

Flea beetles *Phyllotreta* spp. are the early season herbivores of *B. oleracea* plants. Although there are no commercial microbial insecticides against these insects so far, the level of their infestation can influence the number of the following lepidopteran herbivores [11, 12]. For example, *M. brassicae* infestation was significantly more on plants undamaged previously by other insects [11]. In our experiments, the least infestation by flea beetles was registered on red cabbage compared with white cabbage. The preference of white cabbage by this herbivore increased, whereas the number of individuals per plant decreased. As to cauliflower, in 2008, this plant was infested like white cabbage, but the decreased number of flea beetles led to less level of infestation in 2010. This fact could be connected with a role of temperature factor influenced the longevity of cauliflower growth period (3 weeks after planting in 2008 compared with 4 weeks in 2010). Obviously, wax thickness of leaves cannot be the dominant trait judging by our data, although correlation between this parameter and plant infestation by flea beetles was shown by Žnidarčič et al. [20]. If so, the infestation of cauliflower should be significantly more than of white and red cabbage. Possible explanation of the infestation level could be associated with glucosinolates composition. Some authors reported that the increase of glucosinolates content in *Brassica* plants decreased the infestation level of herbivores [16, 21, 22]. In this connection, the evidence of the highest level of glucoraphanin in red cabbage compared with white cabbage and cauliflower [22] is of great interest according to our data. However, the total content of these

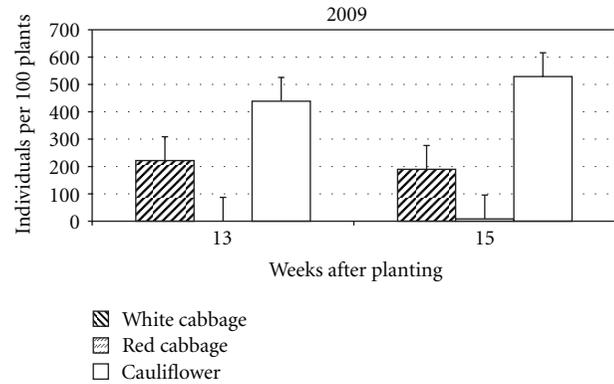


FIGURE 4: Number of *P. brassicae* larvae infested white cabbage, red cabbage, and cauliflower in 2009.

secondary metabolites was the least in cauliflower [22], and that fact could not be correlated with the infestation level of cauliflower compared with two other plant varieties in our experiments. Some data testified the increased content of glucosinolates in *Brassica* plants with the temperature increase and the rainfall decrease [21, 23]. These data can be taken into account for comparison of weather conditions in 2008 and 2010 near Novosibirsk. In addition, it should be realized that flea beetles are early herbivore, and no possible changes in glucosinolate composition occur in plants in this period due to previous damage.

Lepidopteran herbivores started to infest *B. oleracea* plants in 4–15 weeks after planting depending on the insect species and vegetative season (Figures 2–4). *M. brassicae* and *P. xylostella* were the most abundant in the period of observation. The high number of the former was noticed in 2008, and the high number of the latter was in 2009–2010. Contrary to flea beetles, these two herbivores preferred to infest red cabbage most of all. Some authors showed that plant response to attack by generalist and specialist herbivore could differ [5, 24]. However, both *M. brassicae* (generalist) and *P. xylostella* (specialist) infested the same host plant at higher level. Probably, such factors as plant age, leaves thickness, or epicuticular wax layer contribute the plant response to insect attack [20, 25]. As a whole, combination of morphological properties and composition of plant secondary metabolites (glucosinolates) are important for *Brassica* resistance to herbivores [26]. The correlation between quantity of total, aliphatic, or indol glucosinolates in *Brassica* plants and the infestation of the latter by herbivores has been shown by some authors [16, 22, 24]. In addition, the content of glucosinolates in plants could be changed during vegetative period [27, 28]. Red cabbage was shown to contain the least quantity of sinigrin (aliphatic glucosinolate) and its precursor glucoiberin [29] compared with white cabbage and cauliflower. *M. brassicae* and *P. xylostella* infested red cabbage (host plant with minimal content of glucoiberin and sinigrin) at the highest level that confirmed the data of several authors mentioned above. It should be noted that in our laboratory experiments concerning *M. brassicae* rearing on three host plants (Table 3), the largest pupal weight was obtained on red cabbage that confirmed the data obtained in the field.

TABLE 3: Pupal weight of *M. brassicae* reared under laboratory conditions.

<i>Brassica oleracea</i> plants	Pupal weight, mg ($\bar{x} \pm t_{0.5} \times S_{\bar{x}}$)
White cabbage	392 ± 21
Red cabbage	461 ± 15
Cauliflower	410 ± 31

P. brassicae was the latest herbivore infested the plants. Contrary to two other lepidopteran species, this one was not performed on red cabbage and preferred to infest the cauliflower. We suggest that in late period of vegetative season (12–15 weeks after planting) plant age and physical properties of plants become dominant over chemical composition. Covered leaves of cauliflower and two other cabbage varieties as main food for *P. brassicae* larvae differ in quality. Cauliflower forms much more of such leaves around the head compared with red and white cabbage. In addition, in the latter, the leaves become more rigid. The results of laboratory experiments on survival and pupal weight of *P. brassicae* confirmed the data mentioned above (Table 2). Both mass and percent of survived pupae were lowest when rearing on red cabbage. In contrast, under the conditions of different geographical latitude where plants finish their development more quickly, *P. brassicae* caterpillars preferred white cabbage [7].

Beyond the drawing factors, some others can play a role in infestation of *Brassica oleracea* plants by herbivores. For example, elicitors (effectors) contained in oral secretions of larvae are able to trigger defended response of plants associated with herbivore infestation and changed the glucosinolates composition [30–33]. However, it is difficult to take into account all possible factors influenced the final response of plant to insect attack expressed in summary infestation by herbivores.

5. Conclusion

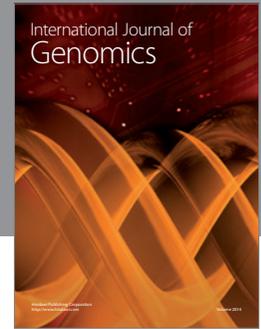
In this paper, we obtained the evidence of different infestation of white cabbage, red cabbage, and cauliflower by the common herbivores in Western Siberia. Flea beetles as the earliest herbivores preferred to infest white cabbage. Contrary to those herbivores, *M. brassicae* and *P. xylostella* larvae infested red cabbage most of all. The latest herbivore of all plants studied, *P. brassicae*, preferred cauliflower but not red cabbage. The possible contribution of some factors in summary effects observed in the study was discussed.

Further studies are being planned in which tritrophic interaction including *B. oleracea* plant, herbivore, and microbial insecticides should be investigated. These studies will help to develop biological insect control of *Brassica oleracea* crops in order to supply ecologically safe plant protection.

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