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Full Length Research Paper

Invasion species *Coleophora laricella* – One of the main limiting factor of *Larix decidua* during the forest aforestation and recultivation

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***Coleophora laricella* Hübner, 1817 was introduced in Serbia along with *Larix decidua* Miller, 1768 (commonly used in the recultivation processes by reforestation) and as a result of the great adaptive ability, it was well-adapted to the site conditions, which differed greatly from the ones within the limits of its nature spread. It is very obstinate and harmful forest insect. In suitable places it has a permanent fluctuation, and in artificial stands the outbreak can last for as long as 12 years, which was confirmed in the common larch cultures established in 1981 at the waste disposal sites of the waste-rock of energy-industrial complex Kolubara, where it started in 1992 and lasted for 15 years. The chemical aerial suppression was conducted in 1996, and the success was complete, but short-lived. However, in the subsequent years, until 2007, the number of the larch casebearer was still above the critical one. The parasitic complex (10 species) was not sufficient for the significant reduction of the population level of the host. The multi-annual consecutive defoliation caused the significant reduction of the current and total increment of the common larch trees, as well as the increase of the intensity of their desiccation.**

Key words: *Coleophora laricella*, outbreak, parasites, reductions in larch growth.

INTRODUCTION

In the second half of the 20th century, the rapidly-growing allochthonous species from genus *Larix* Miller, 1754 and *Pseudotsuga* Carrière, 1867, were very popular in Serbia, and as a result, were frequently used in the processes of recultivation and reforestation. Nowadays, in central Serbia, based on the published data of the forest inventory (Bankovic et al., 2009), there are 995,956 larch trees in total, the volume of which is 107,759.8 m³ and volume increment is 5,167.4 m³.

The larch casebearer, *Coleophora laricella* Hübner, 1817 (Syn.: *Tinea laricella* Hübner, 1817) (Lepidoptera, Coleophoridae) is a widespread monophagous species, to the greatest extent connected to the genus *Larix* (mainly *L. decidua*: Miller, 1768; *L. kaempferi* (Lamb.): Carrière, 1855; *L. occidentalis*: Nuttall, 1849; *L. laricina* (Du Roi): Koch, 1873). Another conditional host is genus *Pseudotsuga*, which was also confirmed by these researches.

C. laricella inhabits the entire Northern hemisphere (Europe, large parts of Asia and North America, where it was introduced in 1886). It is believed that its original habitat is the eastern mid-Alps, whence the host plant European larch (*Larix decidua*) spread into the plains of North-Eastern Europe and further. Today larch casebearer inhabits all areas in which larch grows, which results from its adaptability to site conditions. It occurs not only in upland, but also in lowland areas.

The larch casebearer is a very obstinate and harmful forest insect on dry and sunny areas, as well as in plains and highland. In suitable places it has a permanent fluctuation, and in artificial stands the outbreak can last for as long as 12 years. The L_4-larvae, which intensively feed themselves in the period April to May, destroy

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assimilatory organs of all larch types, but the most jeopardized is European larch because it has short needles and a relatively small number of needles on a short shoot. Larch casebearers attack larches of all age classes, from three-year-old seedlings to mature trees ready for cutting. The attack can be strong in both pure and mixed stands.

MATERIALS AND METHODS

Geographical and climatic characteristics of the study area

The mining-energy-industrial complex ″Kolubara″ is situated 50 km southwest from Belgrade, in the central part of the Peripannonian Serbia in the valley of the Kolubara River and its tributaries, at the altitude ranging from 200 to 300 m. The climate in the Kolubara basin is rather dry, with continental and steppe characteristics. Winter months are characterized by the low precipitation, and as a result, soil is not provided with moisture in the initial stage of vegetation. In the second half of spring, the quantity of rainfall is sufficient, but it is not adequate to mitigate the damage of caused by the summer heat. In addition, in spite of the large quantity of rainfall in June, July and August, it is still insufficient because the extremely high temperatures. In autumn, rainfall is sufficient but not well-timed, because it is distributed at the end of the vegetation period[1].

By the end of the last century, mining works were extended to the area of 140 km^2 of mostly fertile agricultural or forest land. Parallel to the exploitation of waste-rock, the intensive activities were performed in order to revive the devastated area, and the first project of recultivation by afforestation was done as early as in 1977. Total recultivation by afforestation was done on 905.67 ha. Pure larch plantations (European larch *Larix decidua*, Japanese larch *L. kaempferi*) covered the area of 33.26 ha, and mixed with other species they covered the area of 156.24 ha (Schmit et al., 1997).

The selected four experimental plots had the same ecological characteristics in all parts of the area (Picture 1).

Investigations on larch casabearer

The population level of *C. laricella* is determined in the larval instar, and is expressed by the average number of them on the short shoot. Since the number of the needles in the short shoot of the European larch is rather constant (around 40), and as the number of the needles consumed by a larva during the development is known, the density expressed in this way represents the useful piece of information for the prognosis. Since the great variability in the degree of mortality is typical for the larch casebearer, it is difficult to anticipate the number of them in the future, and it is mostly expressed by the critical number which is determined prior to the beginning of the spring abundant eating of L_4 instar. Furthermore, during the very course of the spring activities of the larvae, the whole range of the biotic and abiotic factors influence the population dynamics. According to Schwerdtfeger and Schneider (1957), the critical number implies the number of the healthy individuals of some pest per a site, the activity of which may cause the great damages to the certain site. For *Coleophora laricella* it varied in dependence on the stand conditions, and for North and Middle Europe it ranged from 0.5 to 2 larvae per a short shoot, counted in the late winter (Schwerdtfeger and Schneider, 1957; Eidman, 1965), that is, according to Schindler (1965), for the cultures on the poor, wet soil, with small increment, the critical number is 1 to 2, or 2 larvae per a shoot for the cultures with high increment.

The percentage of the parasitization rate was determined on the representative samples with 500 larvae, which, along with the respective short shoots, were grown in petri dishes under constant laboratory conditions until the moment of hatching of imago parasites or larch casebearer from their dens. The dens on which the exit holes were not noticed, were desiccated in order to determine whether they contained parasites, or larvae, that is, pupae, which died due to some other reasons. In most of them the adult parasites were formed.

Investigations on growth of European larch

The analysis of the diameter and height increment of the larch was conducted in the spring of 2005. The measures were performed on five trees which were imposed to the very strong attack of *C. laricella* throughout the research period, and five control ones, on which during the outbreak the presence of larch casebearer was not registered, that is, on which there was no defoliation. The growth of *Larix decidua* in height and diameter is estimated by dendrochronological analysis of cut down trees.

RESULTS

The presence of the invasive species *C. laricella* in the cultures of European larch established on the waste-disposal sites of waste-rock of mining-energy-industrial complex „Kolubara“, was registered for the first time eleven years after the establishing of the plantation.

In 1992 the health condition of the cultures at some plots started to deteriorate, owning to the activities of the larch casebearer. In the beginning the attack was relatively weak, but in the next April, in the three classes, which were registered as the initial ones in the outbreak, the population level considerably increased, owning to which the tops of the most trees were defoliated. The next generation of *C. laricella*, in the period 1993/1994 occurred in a large number, with the tendency of the further increase in the population level and spread throughout the whole area.

In the spring of 1994 the considerable damages of the needles were registered, as a result of the activities of the larvae. This condition imposed a need for the detailed control of all the older cultures, for the laboratory analysis of the sampled branches, for the accurate determination of the larch casebearer population level, as well as of the level of the endangerment of the larch, as early as in March 1995. The average number of the larvae per a short shoot ranged from 0.08 to 0.39, and did not reflect the actual condition, since the mining of the needles was intensive. Therefore, it was anticipated that the number of this invasive species in the new generation would exceed the critical level in September.

[1] The conclusion derived from the analysis of data provided by Belgrade Meteorological Station.

Picture 1. The mining-energy-industrial complex ″Kolubara″ and experimental plots 1 to 4 (Satellite image of the research area is taken from the ©2010 Europa Technologies Image, ©2010 Digital Globe, ©2010 Ones/Spot Image and ©2010 Google).

Table 1. Population density of *C. laricella* Hübner, 1817 in the period 1996 to 2009.

Date of collecting	Mean number of alive caterpillars per short shoot			
	Experimental plot			
	1	2	3	4
1996 April 22nd	0.80	0.79	0.94	0.81
1997 April 15th	0.84	0.38	0.67	0.76
1998 April 20th	0.90	0.43	0.68	0.71
1999 April 18th	1.17	0.92	1.40	1.33
2000 April 20th	1.02	0.57	0.94	0.72
2001 April 11th	0.41	0,13	0.95	1.05
2002 April 23rd	0.31	0.06	1.09	0.85
2003 April 29th	0.20	0.04	0.94	0.78
2004 April 25th	0.12	0.11	0.91	0.68
2005 April 20th	0.08	0.03	0.73	0.77
2006 April 22nd	0.04	0.03	0.73	0.67
2007 April 27th	0.03	0.02	0.28	0.15
2008 April 15th	0.03	0.03	0.09	0.09
2009 April 13th	0.02	0.02	0.03	0.02

In the early spring of 1996, on the total area of around 400 ha, the aerial suppression of the larch casebearer by the DECIS EC- 2.5 preparation was conducted. The average number of the living caterpillars per a short shoot, prior to the treatment, was below the critical one, and ranged from 0.79 to 0.94. As early as one the first day of the suppression, it was drastically reduced, and ranged from 0.16 to 0.44. After four days it ranged from 0 to 0.03 (Minic et al., 1997).

Nevertheless, the suppression was effective for a short time. The average number of the next generation was still above the critical value, and ranged between 0.38 and 0.84 larvae per a short shoot on the sample plots, that is, from 0.38 to 1.01 in all cultures. This trend continued in the following ten-year period, as well (Table 1).

During this research the possibility of the application of

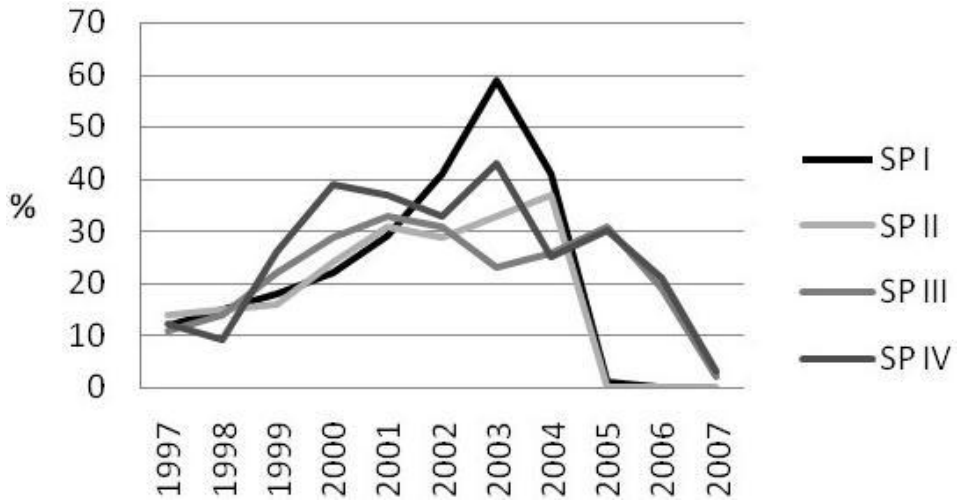

Figure 1. The parasitization rate of larvae and pupae of larch casebearer on the sample plots.

the domestic biological insecticide D-Stop, the active ingredient of which is entomopathogenic bacterium *Bacillus thuringiensis* ssp*. kurstaki*, was analyzed. The biological efficiency of this preparation in the suppression of larch casebearer was tested in the Laboratory of the Institute of Forestry in Belgrade in 1996. However, the results were not good (efficiency was low, below 50%) (Tabakovic-Tosic, 2008).

In the investigated artificially established larch stands, 10 parasite species of larch casebearer were registered (*Diadegma laricinellum*: Strobl, 1904; *Agathis pumila*: Ratzeburg, 1848; *Chrysocharis laeta*: Ratzeburg, 1848; *Chrysocharis laricinellae*: Ratzeburg, 1848; *Cirrospilus pictus*: Nees, 1834; *Necremnus leucarthros*: Nees, 1834; *Necremnus metalarus*: Walker, 1839; *Tetrastichus galctopus:* Ratzeburg, 1844; *Pteromalus* (*Habrocytus) semotus*: Walker, 1834; *Microtus pumilus*: Ratzeburg, 1852), out of which three can be singled out on the criterion of a number (*Agathis pumila*: Ratzeburg, 1848; *Cirrospilus pictus*: Nees, 1834; *Microtus pumilus*: Ratzeburg, 1852) .In the ten-year period (1997 to 2007) of monitoring of the parasitization rate of two instars (larva, pupa) of larch casebearer, the highest level was registered in 2003 (59%). In the period of the largest number of hosts – larch casebearer, there was a considerable increase in the percentage of parasitization rate, which is to be expected (Figure 1).

During this research on larch trees, which were exposed to the intensive defoliation by larch casebearer, and with the well- expressed defoliation, after 3 to 5 years, the considerable reduction of the length and number of needles per short shoot occurred. In the representative samples with 500 short shoots, at the beginning of the outbreak, in 1995, the average number of the needles per shoot was 43.3. In the culmination phase, in 2000, it was 32.6, and at the end of the outbreak, in 2008 and 2009, it was 38.0 and 42.2. The average length of the needles in 1995 was 38.2 mm, in 2000 it was 27.9 mm, in 2008 it was 36.6 mm, and in 2009 it was 37.3.

In addition, the consecutive multi-annual defoliation caused the desiccation of some branches, as well as of the whole trees. In the period 2000 to 2006 there were no attacked trees with the desiccation index 0. The physiological deterioration of the host created the favourable conditions for the harmful effects of other biotic and abiotic agents. As a result, some trees with the desiccation of the tops were registered, owning to the influence of the phytophogous fungi, the agents of the central rot. The trees which physiologically deteriorated in this way are susceptible to *Lachnellula willkommii* (Hartig) Deniss, 1962 and *Heterobasidion annosum* (Fr.) Bref, 1888, which were registered on the individual trees. Since these fungi caused severe damage to European larch (Kurkela, 1983; Phillips and Burdekin, 1982), in the following investigation period, a special attention will be paid to them.

The analysis of the diameter and height increment of the larch, average values,are presented in the Figures 2 and 3.

DISCUSSION

Since the establishment of the European larch cultures on the waste-disposal sites of waste-rock of mining-energy-industrial complex "Kolubara", until today, their health condition has been permanently controlled. In the first eleven years after the recultivation it was concluded that these cultures were vital, biologically stable, and that they developed well. In 1992 the health condition of the cultures at some plots started to deteriorate, owning to the activities of *C.laricella*.

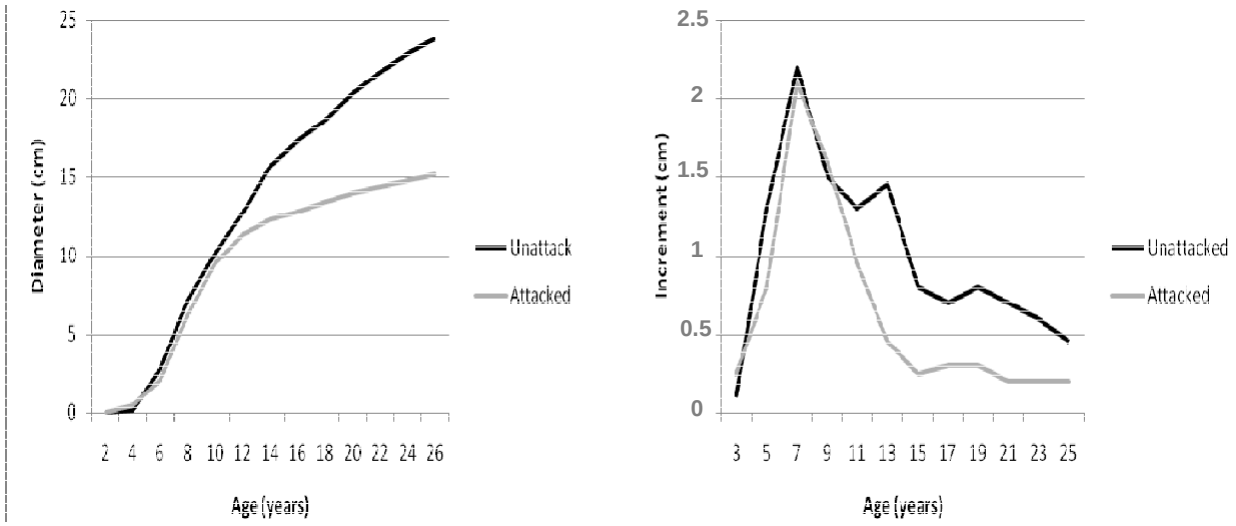

Figure 2. Total and current diameter increment larch trees.

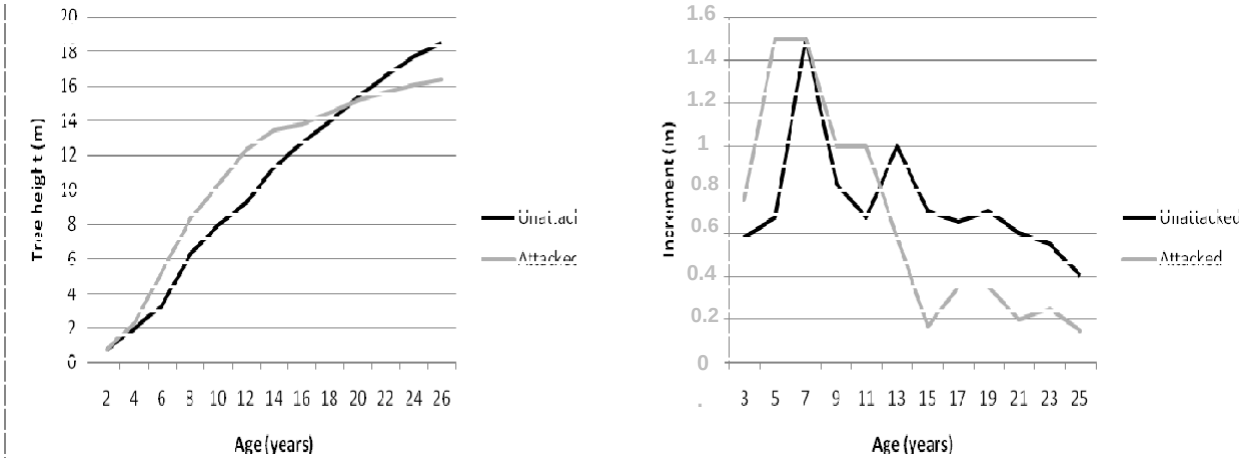

Figure 3. Total and current height increment larch trees.

The European larch almost reached the culminating phase in all cultures of the researched area by 1996, which is typical for the species with the characteristics of outbreak, that is, rapid and significant increase of abundancy and spread. As a result, the appropriate curative measures were urgently taken, and the population level was reduced to the values which did not influence the vitality of the host.

In the early spring of 1996, on the total area, the aerial suppression of the larch casebearer by the chemical preparation was conducted. The control was successful, but as early as in the next generation it was concluded that it lasted for a short time. Since this trend continued in the following ten- year period as well, the general conclusion that the outbreak of the species, *C. laricella*, can be made was artificially established in the larch stands on the recultivated areas of Kolubara. In spite of the application of the repressive control measures, the population level lasted for 15 years. It should be emphasized that the climate change, reflected in the significant melting, that is, relatively high air temperatures in the spring time, enabled the undisturbed development of the young larvae, which are as numerous as other poikolothermic organisms, devoid of well-developed systems of cryoprotectors, to a great extent depend on this abiotic factor.

The reasons for the ineffective aerial suppression conducted in 1996 were not directly investigated, but all the data lead to the conclusion that during the flight of the airplane some areas (for instance, around power line carrier) remained uncovered, and at the later stages they were the center of the spread of this invasive species. In

addition, the suppression of the larch casebearer by the insecticides was hindered owning to the secluded way of life of its larvae, so there is always a possibility that in the tree crowns, some representatives of the population remain harmless. By the application of the chemical preparation the harmony between the population level of the numerous parasite and predatory insects was disturbed, which enabled the undisturbed development of *C. laricella* in the following period.

Natural control factors, such as weather, needle diseases, and native predators and parasites, contribute to the reduction of the population. Some long-term observations of the insect showed that the larch casebearer fluctuates at regular intervals without any detectable effects of predator or parasites on population dynamics (Altenkirch and Winkel, 1990). The other results also showed that predators and parasites seem to be unable to regulate larch casebearer populations (Jagsch, 1973; Tunnock and Ryan, 1985; Long, 1988; Habermann, 1999). The previous activities performed in Europe in the domain of biology (Eidmann, 1965; Jagsch, 1973) and population dynamics (Jagsch, 1973; Altenkirch and Winkel, 1990; Habermann, 1999, 2000) led to the assumption that physiological defense mechanisms of the host plant may cause the cyclic fluctuations of *C. laricella* in its native environment.

In the investigated artificially established larch stands, 10 parasite species of larch casebearer were registered, out of which three can be singled out on the criterion of a number (*Agathis pumila*, *Cirrospilus pictus*, *Microtus pumilus*).

In the ten-year period (1997 to 2007) of monitoring of the parasitization rate of two instars (larva, pupa) of larch casebearer, the highest level was registered in 2003 (59%). In the period of the largest number of host – larch casebearer, there was a considerable increase of the percentage of parasitization rate. At the first glance, the parasite complex did not have a great impact on the reduction of the population level of larch casebearer in the next generation, which was even higher (Table 1, Figure 1). Nevertheless, if the fact that, for instance, in 2003 as much as 40% of population did not participate in the formation of the new generation of the host owning to the parasitization rate, is taken into account, it can be safely assumed that the parasite complex had an important role in this process.

The direct result of the loss of the assimilation apparatus, caused by the nourishment of larvae, is the decrease of the tree fixation capacity. Tree death caused by the larch casebearer is a rare event, but infested larch stands suffer significant growth reductions (Schwerdtfeger and Schneider, 1957; Tunnock and Rayan, 1985; Long, 1988; Alntekirch and Winkel, 1990).

During this research, on larch trees, which were exposed to the intensive defoliation by larch casebearer, and with the well-expressed defoliation, after 3 to 5 years, the considerable reduction of the length and number of needles per short shoot occurred.

Since the beginning of the outbreak of the larch casebearer the permanent increase in the differences in the height and diameter of trees occurred (Figures 2 and 3), and, for instance, at the age of 18 (1998), the diameter of the non-attacked tree is 5.3 cm bigger, in comparison with the attacked one (Figure 2), whereas at the age of 26 it is 8.6 cm. In addition, in the same Figure the differences in the current diameter increment, after the age of 11, that is, from the beginning of outbreak of *C.laricella*, is clearly visible, and there is a similar situation in regard to the tree height. Although the average value in the group imposed no the multi-annual defoliation, before the beginning of the outbreak of larch casebearer was greater, for instance, at the age of 10, by 3 m in average, at the end, at the age of 26, the average height of the attacked tree was 2.1 m smaller in comparison with the non-attacked ones (Figure 3).

Conclusion

The general conclusion which can be derived from all the above facts is that the invasive species *C. laricella* is one of the significant limiting factors of the future selection of the European larch during the processes of the recultivation by reforestation in central Serbia.

REFERENCES

Altenkirch W, Winkel W (1990). Versuche zur Bekämpfung der Lärchenminiermotte (*Coleophora laricella* Hbn.) mit Hilfe insektenfressender Vögel. Waldhygiene, 18: 233-255.

Bankovic S, Medarevic M, Pantic D, Petrovic N (2009). National Forest Inventory of the Republic of Serbia - Forests of the Republic of Serb*ia*. Ministry of Agriculture, Forestry and Water Management - Forest Directory, Belgrade, Serbia, pp. 1-244.

Eidmann HH (1965). Ökologische und physiologische Studien über die Lärchenminiermotte, Coleophora laricella Hbn. Studia Forestalis Suecia, 32: 1-226.

Habermann M (1999). Untersuchungen zur Nadelphysiologie von Lärchen (Larix ssp.) bei Befall durch die Lärchenminiermotte Coleophora laricella Hbn. (Lepidoptera, Coleophoridae*).* Diss. Univ. Göttingen Cuvillier Verlag, Göttingen, p. 191.

Habermann M (2000). The Larch Casebearer and Its Host Tree: II: Changes in needle physiology of the infested trees. Forest Ecology and Management 136(1)3: 23-34

Jagsch A (1973). Populationdynamik und Parasitenkomplex der Lärchenminiermotte, *Coleophora laricella* Hbn, in naturlichen Verbreitungsgebiet der Europaischen Larche, *Larix decidua* Mill. Zeit. ang. Ent., 73: 1-42

Kurkela T (1983). European Larch Canker – Its biology, hosts, site relationships, implications to forestry and the microbiology of cankers. European Larch Canker Workshop. Canadian Forestry Service. MFRC Workshop proceedings, 3: 28-34

Long GE (1988). The larch casebearer in the intermountain northwest. In: Berryman A A (Ed*)* Dynamics of Forest Insects and Populations. New York, 233-242.

Minic D, Marovic R, Markovic D, Tabakovic-Tosic M, Schmit S (1997). Control of Larch Moth (*Coleophora laricella* Nb.) in the Kolubara Basin. Book of articles - International Scientific Symposium ″50 years - Faculty of Forestry″, Skopje, pp. 85-81

Phillips DH, Burdekin DA (1982). Diseases of forest and ornamental trees. Macmillan, London, pp. 166-172.

Schindler U (1965). Zur Bekämpfung der Lärchenminiermotte. Forst u. Holzwirt, 20:1-6

Schmit S, Veselinovic N (1997). Recultivation by Afforestation of Minespoil Banks of Opencast Lignite Mine "Kolubara". Institute of Forestry, Belgrade, p. 147.

Schwerdtfeger F, Schneider G (1957). Uber den Einfluss von Lärchenminiermotten - Frass auf Banadelung und Zuwachs der Lärche. Forstarchiv, 2(6): 113-117

Tabakovic-Tosic M (2008). Entomopathogenic Bacterium *Bacillus thuringiensis ssp. kurstaki* the important componennt of the integral protection of forest ecosystems. Institute of Forestry - Special editions, Belgrade, Serbia, p. 148.

Tunnock S, Rayan RB (1985). Larch Casebearer in Western Larch. US Department of Agriculture – Forest Service. For. Insect Dis., 96:1-7