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Preliminary Survey of Pine Blister Rusts in the Russian Far East

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SUMMARY: Surveys of blister rust fungi were carried out in several areas of the Russian Far East (Eastern Siberia) during 1992-1994. In these surveys, we could collect many specimens of blister rust fungi on *Pinus pumila*, *P. koraiensis* and *P. sylvestris* and those on alternate hosts, i.e. *Ribes* spp., *Pedicularis* spp. and *Paeonia* sp. Two species of blister rust fungi, *Cronartium ribicola*, and *C. flaccidum* were recognized. Possible life cycles of the two species were proposed based on the morphological observation of the fungi and association of *Cronartium* infected plants at the places where the blister rusts occurred. However, uredinial and telial stages found on *Pedicularis* spp. collected in these areas could not be assigned definitely either to *C. ribicola* or *C. flaccidum* and need further investigation.

Key Words: *Cronartium ribicola*, *Cronartium flaccidum*, blister rusts, *Pinus*, Siberia.

INTRODUCTION

In the Russian Far East (Eastern Siberia), *Pinus pumila* (Pallas) Regel, *P. koraiensis* Sieb. et Zucc. and *P. sylvestris* L. are widely distributed (2). Three blister rust fungi, *Cronartium ribicola* J. C. Fisher, *C. kamtschaticum* Joerstad and *C. flaccidum* (Alb. et Schw.) Winter were known to occur commonly on *P. koraiensis*, *P. pumila* and *P. sylvestris*, respectively (1,2). *Pinus densiflora* Sieb. et Zucc. is also planted in small area of southern part of Primorsky Territory and infected with *C. flaccidum* (1,2). Alternate host plants of *C. ribicola* are reported to be *Grossularia reclinata* (L.) Mill., *Ribes dikuscha* Fisch., *R. fragrans* Pall., *R. latifolium* Jancz., *R. mandshuricum* (Maxim.) Kom., *R. nigrum* L., *R. palczewskii* (Jancz.) Pojark., *R. pallidiflorum* Pojark., *R. pauciflorum* Turcz., *R. procumbens* Pall., *R. rubrum* L. and *R. triste* Pall.; of *C. kamtschaticum*, *Castilleja pallida* (L.) Spreng, *Pedicularis chamissonis* Stev., *P. resupinata* L. and *P. sudetica* Willd. and of *C. flaccidum*, *Vincetoxicum amplexicaule* Sieb. et Zucc., *Euphrasia maximowiczii* Wettst. and *Paeonia lactiflora* Pall. (1). However, their taxonomy, life cycle and geographical distribution have not been studied sufficiently.

Recently, two new endo-form species and one variety of blister rust fungi on *Pinus pumila*, *Endocronartium sahoanum* Imazu et Kakishima var. *sahoanum*, *E. sahoanum* var. *hokkaidoense* Imazu et Kakishima, and *E. yamabense* (Saho et I. Takahashi) Paclt, were reported from Japan (6, 7, 8, 9, 10). Taxonomic and phylogenic relationships between the blister rust fungi in the Russian Far East and those in Japan are very interesting. Therefore, we carried out survey of blister rust fungi in several areas of the Russian Far East in order to clarify what and how many species are distributed in this area and what their alternate host plants are.

MATERIALS AND METHODS

Surveys of blister rust fungi were conducted several times during 1992-1994 in four reserved areas in the Russian Far East (Fig. 1). Main areas of surveys and dates of visit are as follows:

Sikhote-Alin Reserve, Primorsky Territory (Fig. 1A):

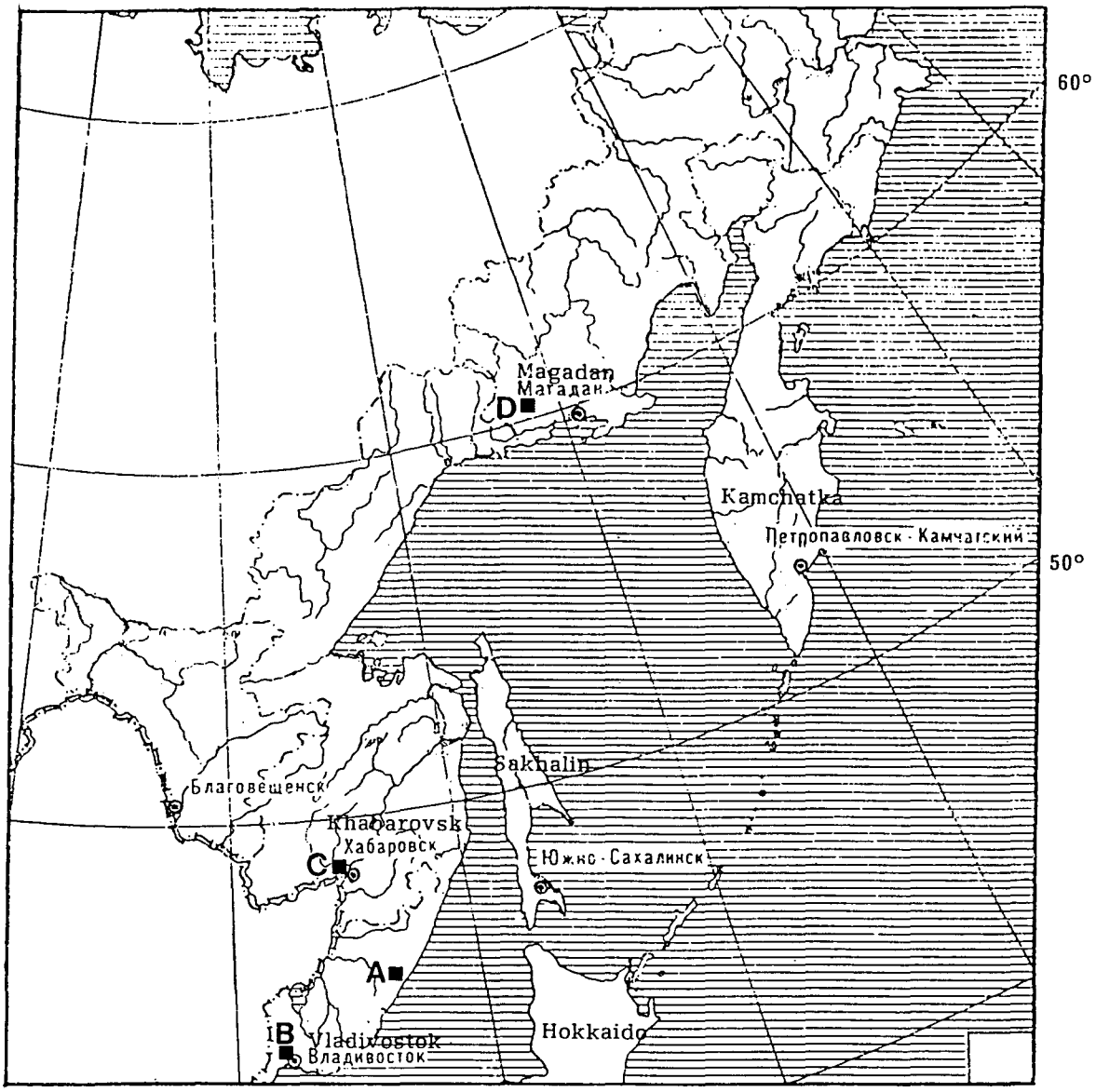

Fig. 1. Main areas of survey of pine rusts in the Russian Far East. A: Sikhote-Alin Reserve, Primorsky Territory. B: Ussuri Reserve and Vladivostok, Primorsky Territory. C:Bolschechtsirsky Reserve, Khabarovsk Territory. D: Contact, Magadan Region.

September 7-14, 1993; July 8-15, 1994.

Ussuri Reserve and Vladivostok, Primorsky Territory (Fig. 1B): July 28-August 7, 1992; September 4-6, 1993.

Bolschechtsirsky Reserve, Khabarovsk Territory (Fig. 1C): August 26-September 3, 1993;July 17, 1994.

Contact, Magadan Region (Fig. 1D): August 18-25, 1993; July 18-23, 1994.

Herbarium specimens were used for morphological observation with light (LM) and scanning electron microscopy (SEM) by the method reported previously (8). For observation of nuclei in spores and their germ tubes, fresh spores germinated on glass slides, which were coated with 0.3% water agar, were stained with HCl-Giemsa. All specimens collected in this survey are deposited in the Mycological Herbarium, Institute of Agriculture and Forestry, University of Tsukuba (TSH).

RESULTS AND DISCUSSION

In Sikhote-Alin Reserve (Fig. 2A), *Pinus koraiensis* is a very common pine tree in the forests. However, it was very rare to find infection of blister rust in spite of careful obser-

vation. *Pinus pumila* is also distributed in small areas in the forests, mostly at the top of mountains. We were not able to find blister rust on *P. pumila* in this Reserve. However, uredinial and telial stages of blister rust fungi were frequently found on *Ribes* spp. and *Pedicularis* spp. Specimens collected and results of their identification are shown in Table 1. Blister symptom (Fig. 2B,C) and aeciospore characteristics (Fig. 2D,E) on *P. koraiensis* were identical with those of *C. ribicola*. We also identified uredinial and telial stages of the rust fungi on *R. mandshuricum* and *R. latifolium* (Fig. 3) as *C. ribicola* because their morphology were similar to those of *C. ribicola* and they were collected at the same area where we found blister rust of *P. koraiensis*. Specimens of uredinial and telial stages on *P. resupinata* and *P. mandshurica* (Fig. 4) were morphologically very similar to those of *C. ribicola* and were collected near *P. koraiensis* which were infected with *C. ribicola*. Moreover, *Pedicularis* species including *P. resupinata* have been known as uredinial and telial hosts of *C. ribicola* in Japan and Korea (4,13,15). Therefore, we suspected that these stages might be those of *C. ribicola*. However, uredinial and telial stages of *C. flaccidum* are also known to occur on *P. resupinata* in Japan and Korea (4,11,14) and are morphologically indistinguishable from those on *C. ribicola*. Distribution of *Pinus sylvestris*, which is an aecial host of *C. flaccidum*, is also recorded in this Reserve (2). From the above reasons, we could not identify these specimens.

In Ussuri Reserve and Vladivostok, *Pinus koraiensis* is commonly distributed and *P. sylvestris* is grown as roadside trees. Distribution of *P. densiflora* is also recorded (2). We could not find blister rusts on these trees because we visited this area in seasons when blister rusts did not sporulate on pines. However, the uredinial and telial stages were found on *Paeonia lactiflora*, *Ribes latifolium* and *Pedicularis resupinata*. These specimens were identified as in Table 2. Uredinial and telial stages on *Paeonia lactiflora* (Fig. 5) were identified as *C. flaccidum* because they were reported as those stages of *C. flaccidum* in the Russian Far East (1) and were morphologically identical with those stages of C. *flaccidum*. *Ribes latifolium* is known as a uredinial and telial host of *C. ribicola* in this area and there were no morphological differences between the rust on *R. latifolium* and *C. ribicola*. The specimens on *P. resupinata* could not be identified because of the same reasons as in Sikhote-Alin Reserve.

In Bolschechtsirsky Reserve, *Pinus koraiensis* is also naturally distributed and *P. sylvestris* is grown in small plantations. We could not find any blister rust infections of *P. koraiensis*. However, we found *P. sylvestris* heavily infected with a blister rust and also uredinial and telial stages on *Ribes mandshuricum* and *Pedicularis resupinata*. These specimens were identified as in Table 3. Blister symptom (Fig. 6A,B) and aeciospore characteristics (Fig. 6C,D) on *P. sylvestris* were similar to those of *C. flaccidum*. However, we were not able to find the uredinial and telial stages on possible host plants. End-form species, *Endocronartium pini* (Pers.) Y. Hiratsuka whose teliospores are morphologically identical with aeciospores of *C. flaccidum*, have been known to occur on *P. sylvestris* in Europe, but not in Russia (5,12). Examination of nuclear behavior during spore germination will be required to elucidate the identification. Telial columns on *R. mandschuricum* (Fig. 7) were frequently observed and

Table 1. Specimens and results of identification of blister rust fungi collected in Sikhote-Alin Reserve.

Species	Stage	Host plant	Specimen No.(TSH-R)
Cronartium ribicola	0, I	*Pinus koraiensis*	8922,8992,9156,9157,9193,9194,9202,9237
	II, III	*Ribes mandshuricum*	8905,9143,9170
		R. latifolium	8956,9120
Cronartium sp.	II, III	*Pedicularis resupinata*	8899,8985,9000,9161,9203
Cronartium sp.	II, III	*Pedicularis mandshurica*	8993

Table 2. Specimens and results of identification of blister rust fungi collected in Ussuri Reserve and Valdivostok.

Species	Stage	Host plant	Specimen No.(TSH-R)
Cronartium flaccidum	II, III	*Paeonia lactiflora*	8896,9113
Cronartium ribicola	II, III	*Ribes latifolium*	9014,9020,9029,9071,9077
Cronartium sp.	II, III	*Pedicularis resupinata*	9036,9085

were identified as those of *C. ribicola*. The specimens of uredinial and telial stages on *P. resupinata* (Fig. 8) could not be identified because of the same reason in Sikhote-Alin Reserve.

In Reserves in Magadan Region (Fig. 9A), *Pinus pumila* (Fig. 9B) is the only species of *Pinus* distributed in this area. We were able to find *P. pumila* heavily infected with blister rust fungus at many places in mountains. We also collected *Ribes fragrans* (Fig. 11A,B), *R. triste* (Fig. 11C,D) and *R. dikuscha* infected with uredinial and telial stages of blister rust fungi in these mountains. We carefully observed *Pedicularis* species in these areas. However, we could not find blister rust infections. The specimens collected there were identified as in Table 4. We identified the blister rust fungus on *P. pumila* as *C. ribicola* because symptoms ((Fig. 9C,D,E) and aeciospore characteristics (Fig. 10A,D,E) were very similar to those of *C. ribicola*, and we observed that its uredinial and telial stages occurred on *Ribes* spp. growing beside *P. pumila* which were infected with blister rust fungus (Fig. 9b). Morphology of uredinial and telial stages on *Ribes* spp. (Fig. 12) was also similar to those of *C. ribicola*.

Kuprevich and Tranzschel (12) and Azbukina (1,2) reported that blister rust fungus on *P. pumila* was *Cronartium kamtschaticum* (= *Peridermium kurilense* Dietel) of which uredinial and telial stages occurred on *Castilleja pallida*, *Pedicularis chamissonis*, *P. resupinata* and *P. sudetica* and widely distributed in the Russian Far East, especially in Magadan Region, Sakhalin and Kamchatka. However, we observed in Magadan Region that alternate hosts of blister rust fungus on *P. pumila* were *Ribes* spp. and identified it as *C. ribicola*. Yokota and Uozumi (15) treated *C. kamtschaticum* as a synonym of *C. ribicola*. However, taxonomic relationships between these two species are need to be clarified. Moreover, we think that reexamination of taxonomic treatment of *P. kurilense* is also required though Hiratsuka (3) and Azbukina (1) considered this blister rust fungus as *C. kamtschaticum*.

Recently, two end-form species and one variety on *Pinus pumila* were reported from Japan (6,7,8,9,10). We examined nuclear behavior during the germination of spores from *P. pumila* collected in Magadan Region and observed that nuclei in spores and their germ tubes were constantly two (Fig. 10C,B). We could not find end-form species in this Region. However, we think that there are possibility to find these species in the Russian Far East, especially in Sakhalin, Kamchatka and Kuril Islands.

From the results of our survey, the possible life cycle of blister rust fungi in the Russian Far East is shown in Table 5. Alternate hosts of *C. flaccidum* on *Pinus sylvestris* may be *Paeonia* and *Pedicularis* because we found *Paeonia* and *Pedicularis* infected with blister rust fungi in Ussuri and Bolschechtsirsky Reserves where *C. flaccidum* was found frequently. We suppose that there are two types of life cycles in *C. ribicola*. In the first type of life cycle, host alternation may occur between *P. koraiensis* and *Ribes* and *Pedicularis*. This type of life cycle was suggested from the survey in Sikhote-Aline Reserve. The second type was suggested from the survey in Magadan Region. In this type of life cycle, host alternation may occur between *P. pumila* and *Ribes*. To confirm these life cycles further survey and inoculation experiments will be required.

Table 3. Specimens and results of identification of blister rust fungi collected in Bolschechtsirsky Reserve.

Species	Stage	Host plant	Specimen No.(TSH-R)
Cronartium flaccidum	0, I	*Pinus sylvestris*	8822,9243
Cronartium ribicola	II, III	*Ribes mandshuricum*	8828,8849,8881,9238
Cronartium sp.	II, III	*Pedicularis resupinata*	8825

Table 4. Specimens and results of identification of blister rust fungi collected in Magadan Region.

Species	Stage	Host plant	Specimen No.(TSH-R)
Cronartium ribicola	0, I	*Pinus pumila*	8759,8764,8765,8789,8790,8799,8809, 9251,9252,9253,9269,9270,9271,9272
	II, III	*Ribes dikuscha*	8769
		R. fragrans	8791,8793,9267
		R. triste	8767

Table 5. Possible life cycle of blister rust fungi in the Russian Far East.

Cronartium flaccidum	
0, I on *Pinus silvestris*	II, III on *Paeonia, Pedicularis*
Cronartium ribicola	
(1) 0, I on *Pinus koraiensis*	II, III on *Ribes, Pedicularis*
(2) 0, I on *Pinus pumila*	II, III on *Ribes*

Acknowledgements

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LITERATURE CITED

1. Azbukina, Z. M. 1984. The manual of rust fungi in Soviet Far East. Nauka, Moscow. 288 pp.
2. Azbukina, Z. M. 1995. *Cronartium* species on *Pinus* species in the Russian Far East. pp. 65-69 in: Proc. 4th IUFRO Rusts of Pines Working Party Conf., Tsukuba.
3. Hiratsuka, N. 1935. A contribution to the knowledge of the rust-flora in the alpine regions of high mountains in Japan. Mem. Tottori Agric. Coll. 3: 125-247.
4. Hiratsuka, N., Sato, S., Katsuya, K., Kakishima, M., Hiratsuka, Y., Kaneko, S., Ono, Y., Sato, T., Harada, Y., Hiratsuka, T., and Nakayama, K. 1992. The rust flora of Japan. Tsukuba Suppankai, Tsukuba. 1205 pp. + Index.
5. Hiratsuka, Y. 1969. *Endocronartium*, a new genus for autoecious pine stem rusts. Can. J. Bot. 47: 1493-1495.
6. Imazu, M. and Kakishima, M. 1992. A new variety of *Endocronartium sahoanum* found in Hokkaido, Japan. Trans. Mycol. Soc. Japan 33: 167-176.
7. Imazu, M. and Kakishima, M. 1995. The blister rusts on *Pinus pumila* in Japan. pp. 27-36 in: Proc. 4th IUFRO Rusts of Pines Working Party Conf., Tsukuba.
8. Imazu, M., Kakishima, M. and Kaneko, S. 1989. *Endocronartium sahoanum*, a new stem rust fungus on *Pinus pumila* in Japan. Trans. Mycol. Soc. Japan 30: 301-310.
9. Imazu, M., Kakishima, M. and Katsuya, K. 1991. Morphology and nuclear cycle of *Endocronartium yamabense*. Trans. Mycol. Soc. Japan 32: 371-379.
10. Imazu, M., Kakishima, M. and Katsuya, K. 1991. Morphology, cytology and taxonomy of stem rusts on five-needle pines in Japan. pp. 76-91 in: Rusts of pines, Proc. IUFRO Rusts of Pine Working Party Conf. (Ed. by Hiratsuka, Y. et al.), Northern Forestry Centre, Edmonton, Canada.
11. Kakishima, M., Hiratsuka, Y., Shibata, H. and Sato, S. 1984. *Cronartium* blister rust on *Pinus densiflora* having *Pedicularis resupinata* var. *caespitosa* as an alternate host. Trans. Mycol. Soc. Japan 25: 315-318.
12. Kuprevich, V. K. and Tranzschel, V. G. 1957. Cryptogamic plants of the USSR, Vol. IV. Fungi (1). Rust fungi No. 1. Komarov Institute of Botany, Moscow-Leningrad. 396 pp.
13. La, Y. J. and Yi, C. K. 1985. Blister rust of Korean pine and its control in Korea. pp. 137-144 in: Proc. Joint Conf. IUFRO Working Parties on Forest Gall Midges and Rusts of Pines (Ed. by Ko, J. H. and La, Y. J.), Korean Forestry Society, Suweon, Korea.
14. Yi, C. K., Kim, H. J. and La, Y. J. 1985. *Cronartium flaccidum* found on *Pinus densiflora* in Korea. pp. 149-161 in: Proc. Joint Conf. IUFRO Working Parties on Forest Gall Midges and Rusts of Pines (Ed. by Ko, J. H. and La, Y. J.), Korean Forestry Society, Suweon, Korea.
15. Yokota, S. and Uozumi, T. 1976. New developments in white pine blister rust in Japan. pp. 330-343 in: Proc. XVI IUFRO World Congress, Oslo.

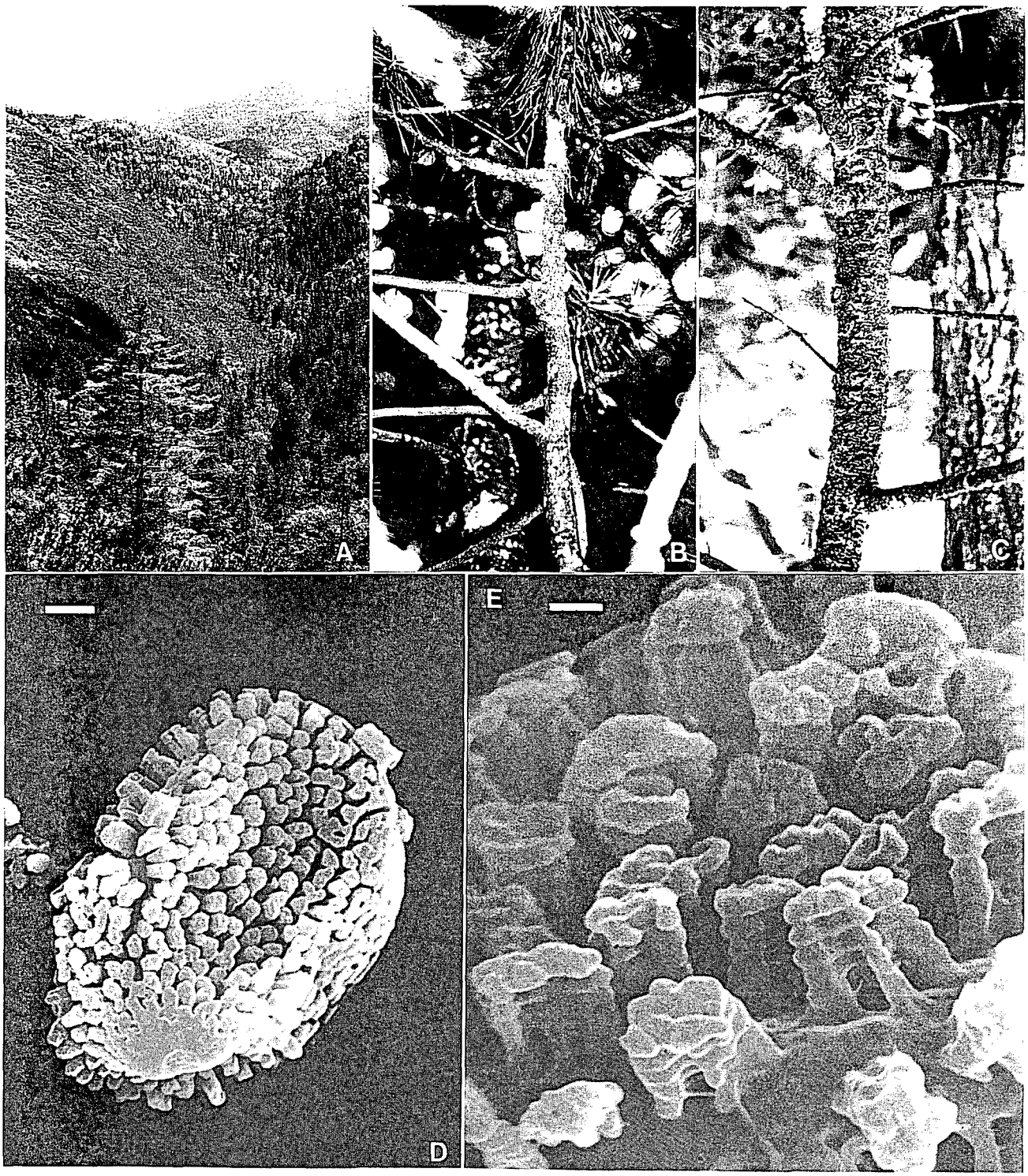


Fig. 2. Sikhote-Alin Reserve. A: View of mountains. B,C: Blister rusts on *Pinus koraiensis* caused by *Cronartium ribicola*. D, E: An aeciospore (D) and its surface structure (E) of *C. ribicola* on *P. koraiensis* observed by SEM. (Scale bars: D= 2 μm, E=0.5 μm).

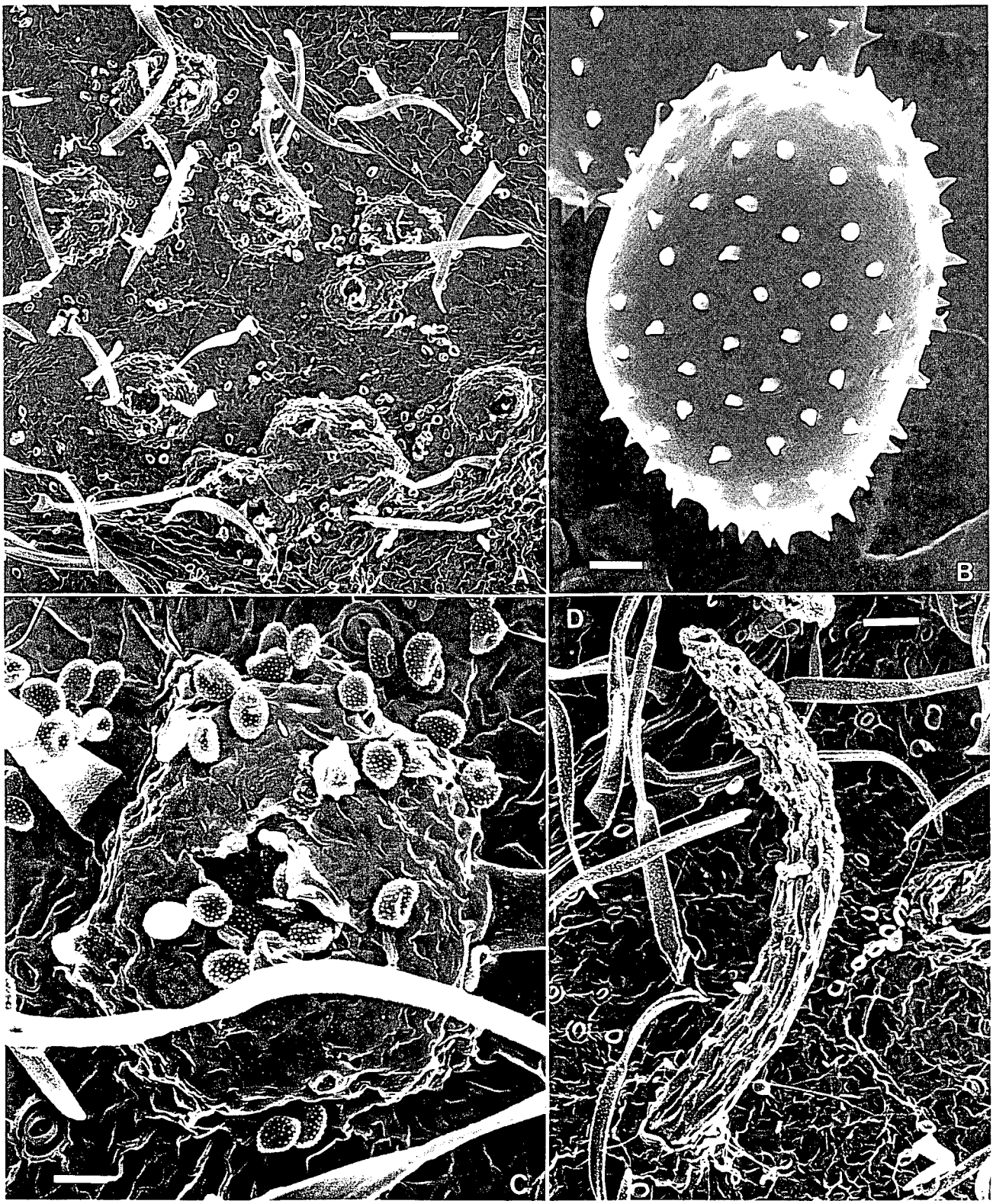


Fig. 3. *Cronartium ribicola* on *Ribes* spp. collected in Sikhote-Alin Reserve and observed by SEM. A: Uredinia on *R. mandschuricum*. B: A urediniospore on *R. latifolium*. C: A uredinium on *R. latifolium*.. D: A telial column on *R. mandschuricum*. (Scale bars: A= 100 μm, B= 2 μm, C= 20 μm, D= 50 μm).

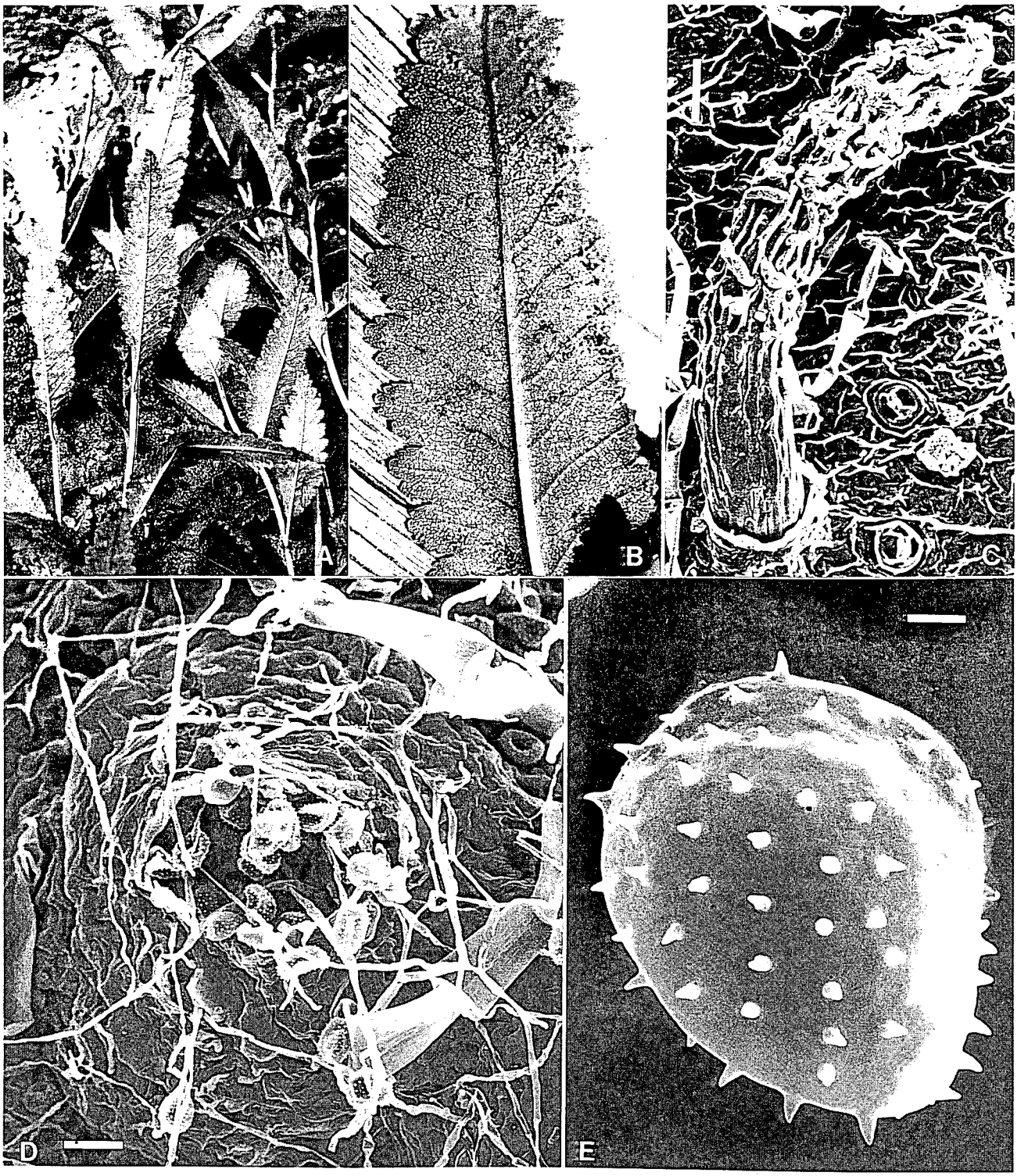


Fig. 4. *Cronartium* spp. on *Pedicularis* spp. collected in Sikhote-Alin Reserve. A,B: Uredinia (A) and telia (B) on *P. resupinata*. C,D: A telial column (C) and a uredinium (D) on *P. resupinata* observed by SEM. E: A urediniospore on *P. mandshurica* observed by SEM. (Scale bars: C= 50 μm, D= 20 μm, E= 2 μm).

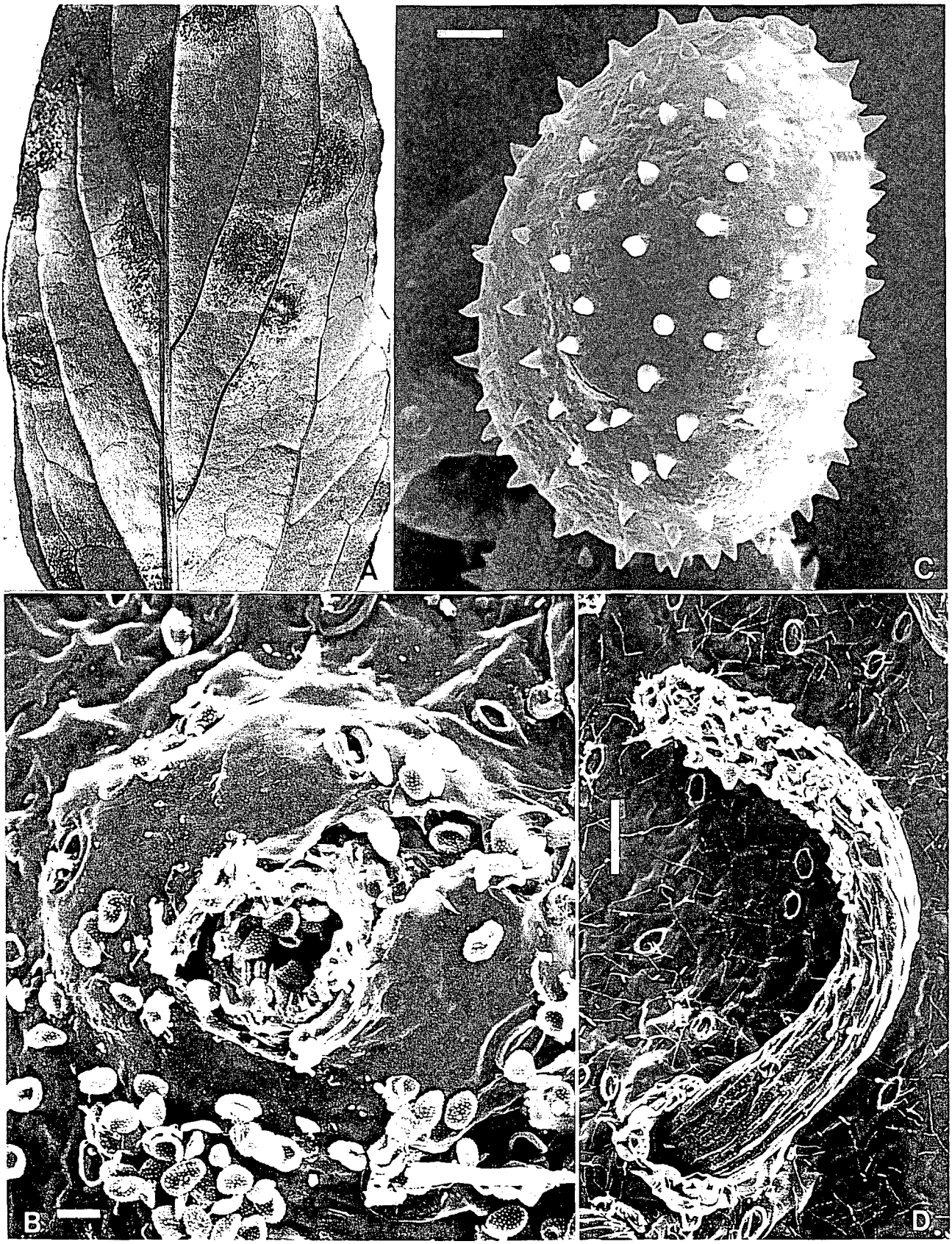


Fig. 5. *Cronartium flaccidum* on *Paeonia lactiflora* collected in Vladivostok. A: telia and uredinia. B,C,D: A uredinium (B), a urediniospore (C) and a telial column observed by SEM. (Scale bars: B= 20 μm, C= 2 μm, D= 50 μm).

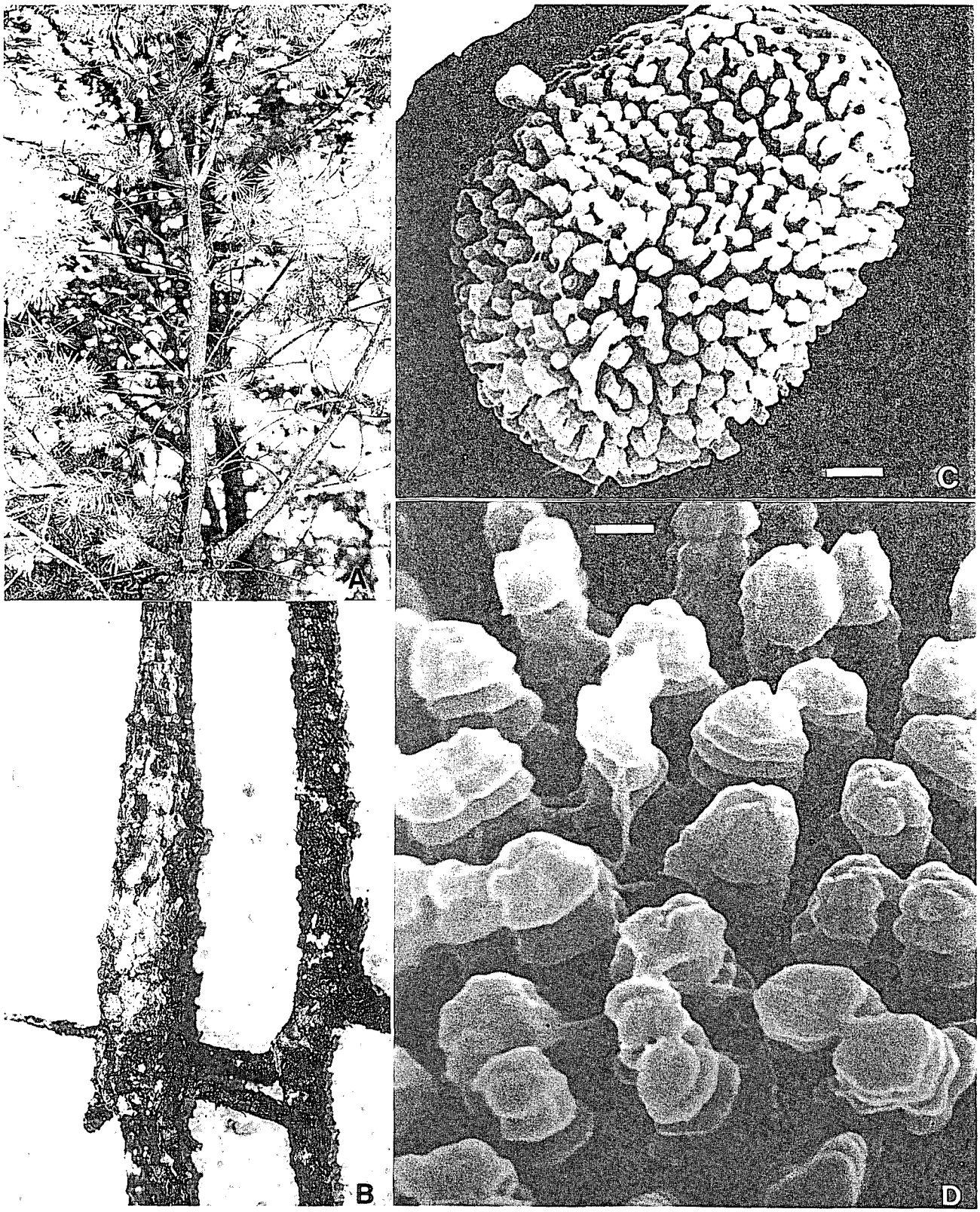


Fig. 6. Blister rust on *Pinus sylvestris* caused by *Cronartium flaccidum* in Bolschechtsirsky Reserve. A,B: Blister symptom. C,D: An aeciospore (C) and its surface structure (D) observed by SEM. (Scale bars: C= 2μm, D= 0.5μm).

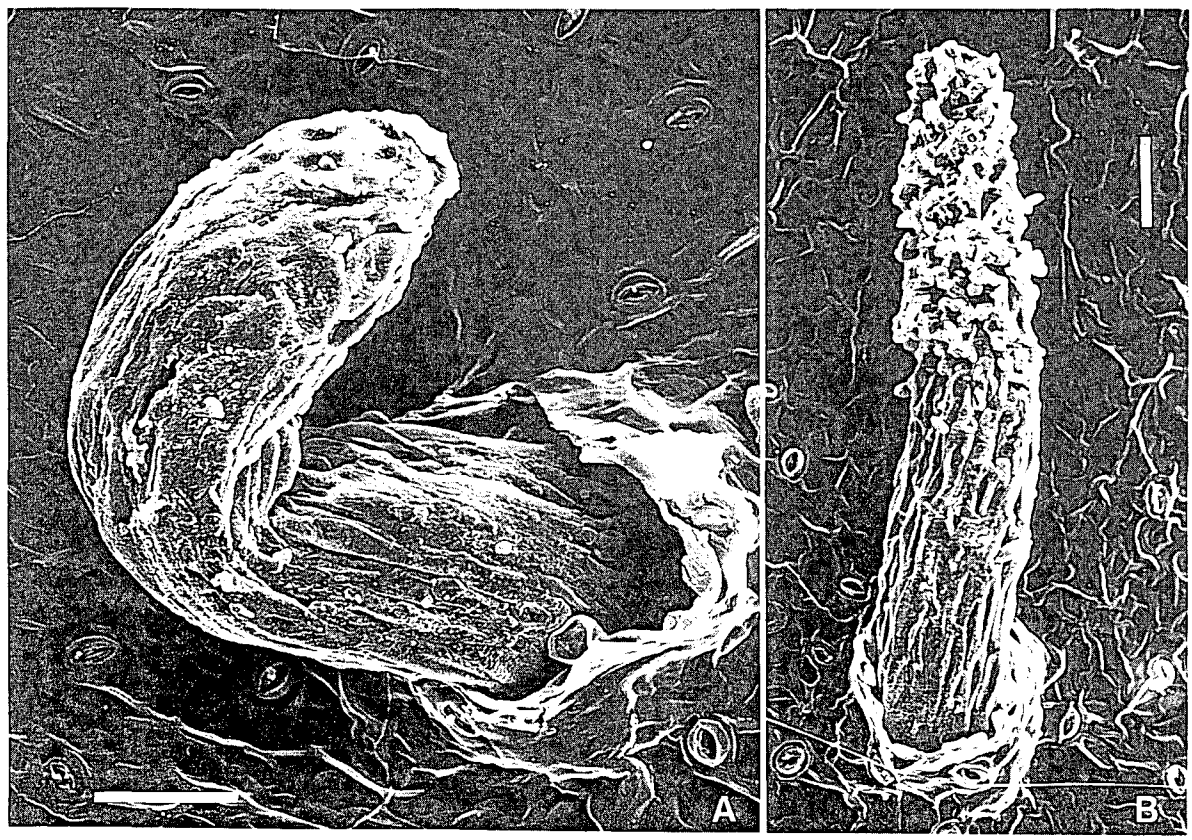


Fig. 7. Telial columns of *Cronartium ribicola* on *Ribes mandshuricum* collected in Bolschechtsirsky Reserve and observed by SEM. (Scale bars: A,B= 50 μm).

Fig. 8. *Cronartium* sp. on *Pedicularis resupinata* collected in Bolschechtsirsky Reserve. A: Uredinia and telia. B: Telial columns observed by SEM. (Scale bar: B= 50μm).

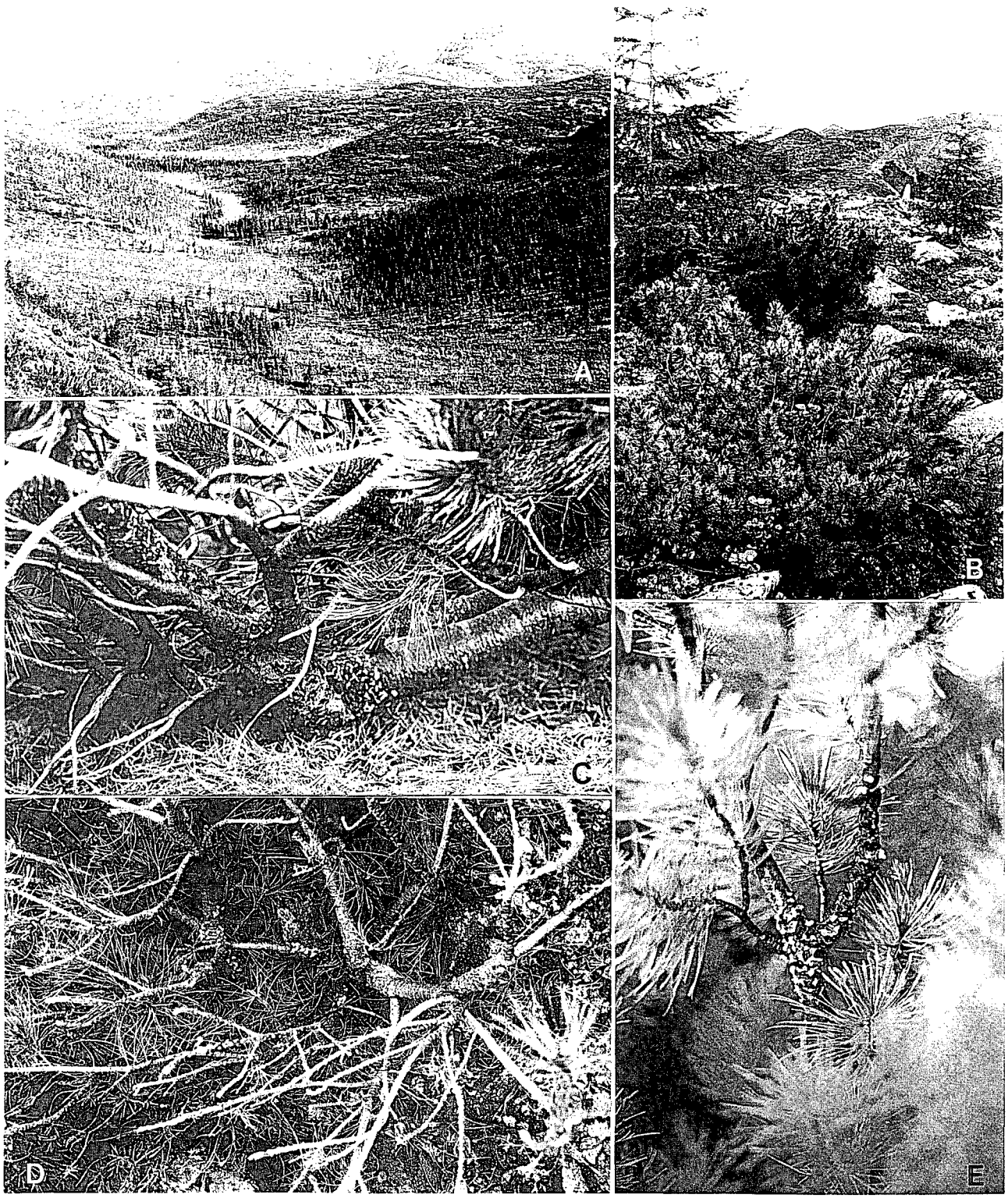


Fig. 9. Contact in Magadan Region. A: View of mountains. B: *Pinus pumila* closely associated with *Ribes fragrans*. C,D,E: Blister rust on *P. pumila* caused by *Cronartium ribicola*.

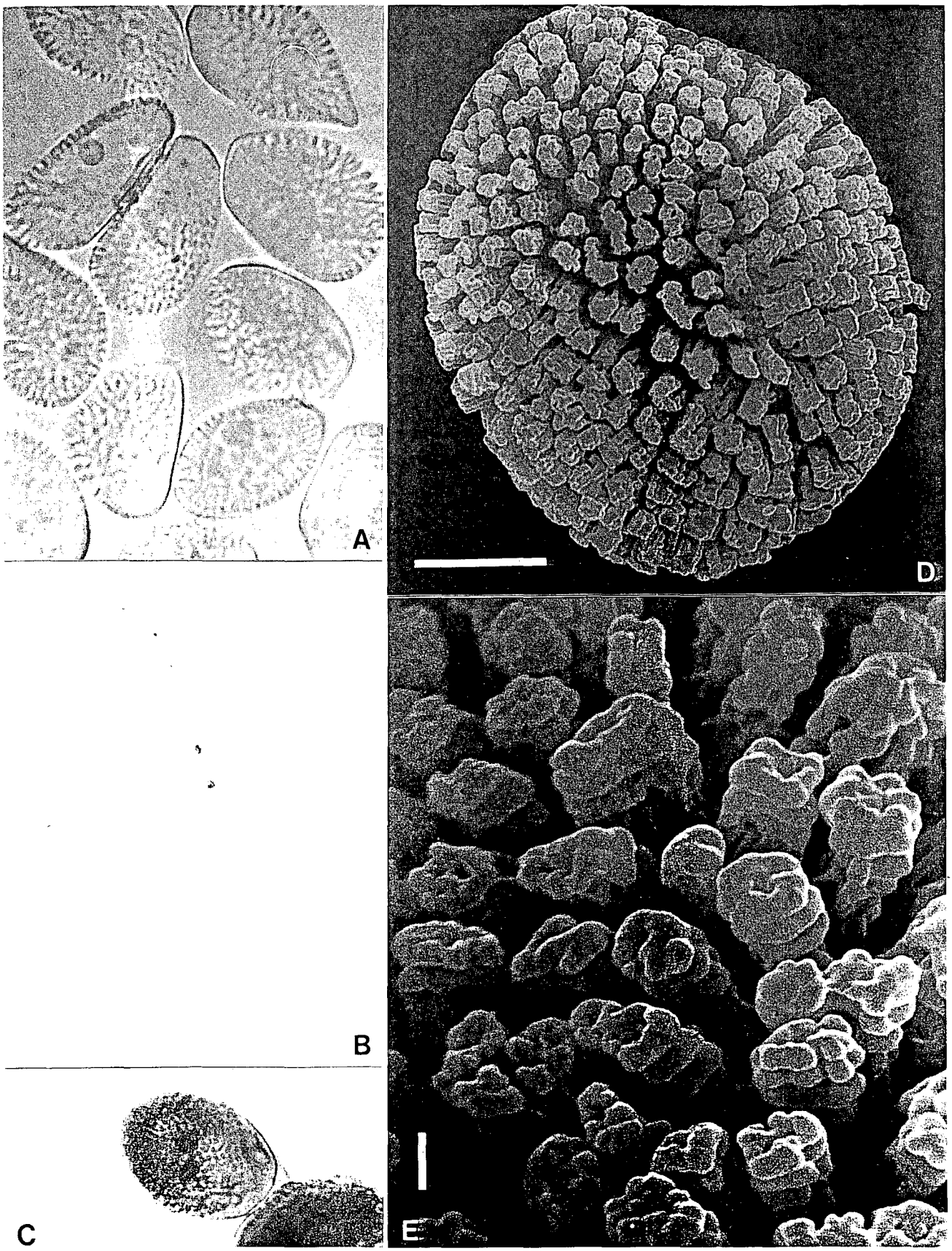
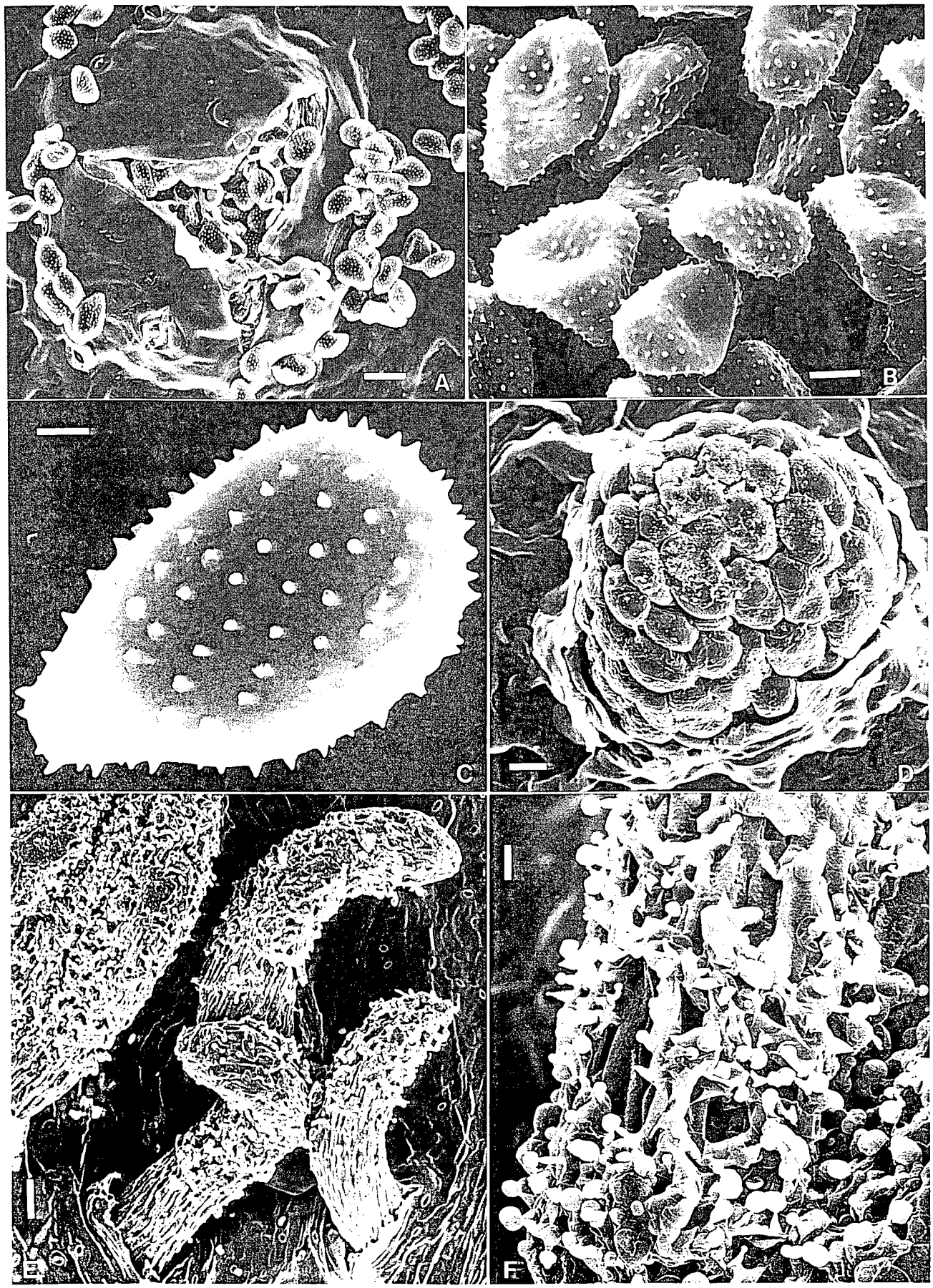


Fig. 10. *Cronatrtium ribicola* on *Pinus pumila* collcted in Contact, Magadan Region. A: Aeciospores. B: Two nuclei in a germ tube of an aeciospore. C: Two nuclei in an aeciospore. D,E: An aeciospore (D) and its surface structure (E) observed by SEM. (Scale bars: D= 5 μm. E= 0.5 μm).

Fig. 11. *Ribes* spp. infected with *Cronartium ribicola* in Contact, Magadan Region. A: *Ribes fragrans*. B: Telia on *R. fragrans*. C: *Ribes triste*. D: Telia on *R. triste*.

Fig. 12. *Cronartium ribicola* on *Ribes* spp. collected in Contact, Magadan Region and observed by SEM. A,B,C: A uredinium (A) and urediniospores (B,C) on *R. fragrans*. D: A telial column on *R. triste*, just after emergence. E,F: Telial columns (E) and basidiospres on a telial column (F) on *R. fragrans*. (Scale bars: A= 20 μm, B= 5 μm, C= 2 μm, D,F= 10 μm, E= 50 μm).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