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RUBUS ARCTICUS L. AND ITS CULTIVATION

Selostus: Mesimarja (Rubus arcticus L.) ja sen viljely

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Agricultural Research Centre
South Savo Experiment Station
Mikkeli, Finland

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RUBUS ARCTICUS L. AND ITS CULTIVATION

RYYNÄNEN, ANNIKKI 1973. **Rubus arcticus L. and its cultivation.** Ann. Agric. Fenn. 12: 1—76.

Rubus arcticus L. is in effect self-sterile, owing to incompatibility. Natural pollination is best ensured by growing different strains close to each other, e.g. in alternate rows. The chief pollinating agents are bumble-bees and honey-bees.

The type of soil or acidity of the substrate was not found to play a decisive role.

R. *arcticus* benefits by a nutrient-rich substrate. In two experiments, Garden Super Y fertilizer, given at rates of 4 and 8 kg/are two to three years after planting out clearly increased the berry yield and the size of the berries.

R. *arcticus* was planted out on level ground with intervals of 1—1.2 m between the rows. Paths were made between the rows, and the plants spread over the rest of the area. The crops were renewed at intervals of four to five years.

The berries were kept clean by covering the soil surface with, for example, fresh sphagnum moss, wood chips or Leca gravel.

The berry yields increased as R. *arcticus* spread. They were largest in the third or fourth summer, including the year of planting out. The best yields were ca. 40—60 kg/are.

On average, the berry contained 20—35 drupelets (maximum 101) and its weight was about 1 g (largest berry 4.6 g).

Preliminary investigations of the quality of the berries revealed differences between the strains in the content of soluble dry matter (sugars) and the acid content.

An increase in the rate of fertilizer application decreased the content of soluble dry matter and thus weakened the taste.

The aroma and colour of half-ripe berries improved somewhat with short storage. If picked when ripe, the berries kept poorly.

INTRODUCTION

Rubus arcticus L., known as the arctic bramble or arctic raspberry, but in the author's opinion more suitably named the nectarberry, has berries with especially fine flavour. The combined distributions of this species and the closely related R. *acaulis* Michx. and R. *stellatus* Sm. form a circumpolar belt stretching almost right round the northern hemisphere. R. *arcticus* itself is clearly commonest in Fennoscandia, especially in Finland.

The species seems to favour various man-made habitats. The burning-over, open-ditching and other soil-exposing activities practised in Finland in the nineteenth century provided it with numerous suitable sites. However, the spread of modern settlement and agriculture in latter decades has been so deleterious to the nectarberry that its berries have become almost scarce.

Attempts to cultivate R. *arcticus* were first made at least 200 years ago. Carl von LINNÉ (LINNAEUS 1762) reported that he had performed successful cultivation experiments in the garden of the Department of Botany at Uppsala University. However, the literature does not appear to contain any contemporary or later accounts of the spread of its cultivation.

In Finland, interest in its cultivation awoke several decades ago. In the 1930s a decrease in the occurrence of R. *arcticus* was noted at the North Savo Agricultural Experiment Station of the Agricultural Research Centre, situated at Maaninka (63°09′ N latitude) in the optimal area of the occurrence and fruiting of the species (SAASTAMOINEN 1930). Through the initiative of Mr. M. SALMINEN, cultivation experiments were begun with R. *arcticus* in 1933, plants being transferred from the vicinity of the station to an experimental field.

Research on R. *arcticus* was interrupted in the 1940s at the time of the Second World War. It was resumed at the station in 1960 and continued till 1970. The author was engaged in this research from 1939 onwards.

Research is still in progress, but it has already proved possible to commence practical cultivation. A handbook on the cultivation of the nectarberry was published in spring 1971 (RYYNÄNEN 1971). In summer 1970 certain nurseries received material for propagation from the North Savo Agricultural Experiment Station, and the sale of plants began in spring 1972.

The aim of the research was to elucidate the biology of R. *arcticus* in general and, in particular, the factors controlling fruiting in the different strains. It was also wished to ascertain the most favourable conditions for its cultivation with regard to: soil type and acidity, planting time and method, care of the soil surface, protection of the plants and application of fertilizers. Attention was also paid to the quality of the berries.

The material consisted of strains collected in nature all over Finland and plants obtained by crossing. Over the years, a fairly extensive stock of plants was accumulated, from which the individuals best suited for cultivation were selected in various ways. The total area of the experimental fields in 1970 was about 40 ares. Comparative investigations of selected material were begun in 1971 at the South Savo Agricultural Experiment Station and at the Department of Horticulture of the Agricultural Research Centre.

It will be of especial importance in the immediate future to include R. *arcticus* among the other cultivated berry plants in attempts to produce healthy material for planting out.

II REVIEW OF THE LITERATURE

1. Taxonomy and general distribution

The genus *Rubus* L., which belongs to the family *Rosaceae*, comprises 12 subgenera. *Rubus arcticus* L. belongs to the subgenus *Cylactis*, being one of the species of the phylogenetic *Arctici* group. Other members of this group are R. *acaulis* Michx., a subspecies of R. *arcticus*, and R. *stellatus* Sm. (LARSSON 1969, HULTÉN 1971).

R. *arcticus* is distributed throughout subarctic Eurasia, in Europe mainly between 60° and 70° N latitude, in Asia between 50° and 70° N, and also occurs in North America, but only in Alaska and the Yukon. R. *acaulis* has its distribution in North America, chiefly in Canada between 50° and 60° N, and Alaska. R. *stellatus* occurs in the Pacific area in Alaska and the Yukon, the Aleutian Islands and Kamchatka (ČERNOVA 1959, LARSSON 1969, HULTÉN 1971. Fig. 1).

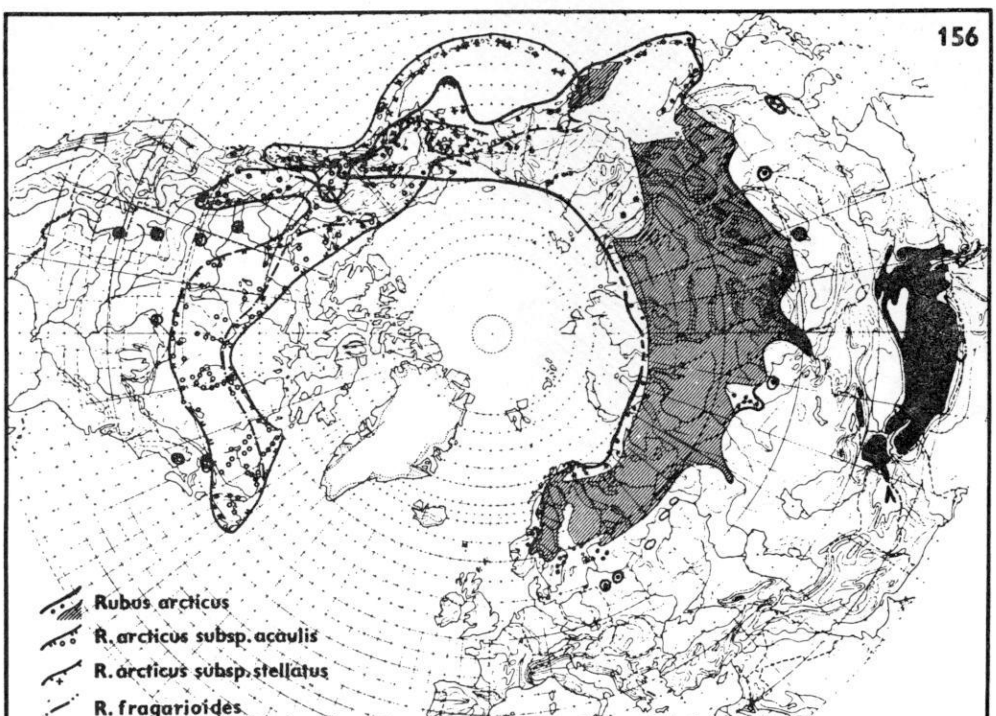


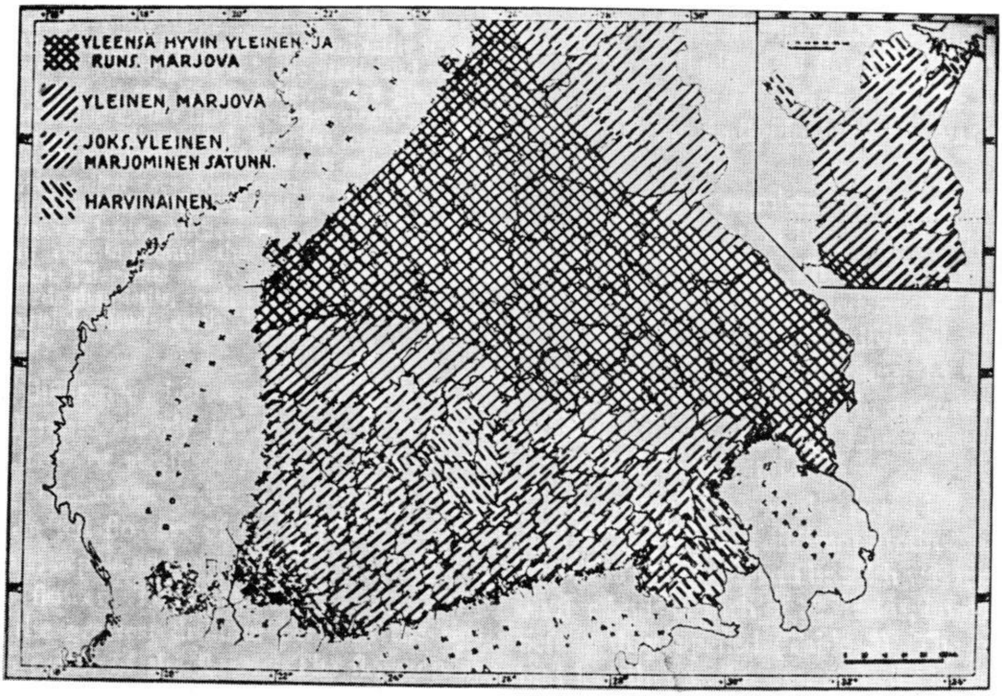
Fig. 1. General distribution of R. *arcticus* and its subspecies (HULTÉN 1971).
Kuva 1. Mesimarjan ja sen alalajien yleinen levinneisyys.

LARSSON (1969) supposes that R. *stellatus* may be a hybrid between R. *arcticus* and R. *acaulis* being found in the area where their distributions overlap. She further reports that the berries of R. *stellatus* when fully ripe have a weak *arcticus*-aroma, whereas it is lacking in the berries of R. *acaulis* as is supposed according to information from a Canadian research station.

The genetic affinity of the taxa of the genus *Rubus* is apparently large. It is therefore natural that intensive spontaneous hybridization takes place in areas where they meet or overlap. However, HULTÉN (1971) is of the opinion that R. *stellatus* is neither a hybrid nor a species, but a subspecies of R. *arcticus* resembling R. *acaulis*.

R. *arcticus* has not been recorded from Iceland and Greenland (LAGERBERG 1939).

In Eurasia the distribution area of R. *arcticus* extends without interruption from the Bering Strait to the Atlantic, and includes the whole of Siberia. In Asia the southern limit of the disjunct occurrences runs as far south as 41° N (in China), but its distribution is concentrated between 50° and 60° N. The Baikal region is considered to be the best area for the species in Siberia, and Karelia the best in the European



Generally very common and fruiting abundantly

Common, fruiting

Fairly common, fruiting occasionally

Rare

Fig. 2. Frequency and fruiting of R. *arcticus* in different parts of Finland (SAASTAMOINEN 1930).
Kuva 2. Mesimarjan yleisyys ja marjomisen määrä Suomen eri osissa.

part of the USSR (FREINDLING 1949, ČERNOVA 1959).

R. *arcticus* was still fairly common in the last century in Estonia, where it is considered a relict of the subarctic conditions following the last ice age. Recently it has become increasingly rarer, so that it is now one of the protected plants in that country. It also occurs in Ingermanland and in Lithuania (EICHWALD 1959 and 1970, EILART 1965).

R. *arcticus* has been reported from the British Isles, but is apparently no longer found there (HARLEY 1956).

In Scandinavia (SAASTAMOINEN 1930), the southern limit of the Swedish distribution of R. *arcticus* lies at the latitude of Stockholm, but it is common only along the coast of the Gulf of Bothnia and in Lapland. It fruits comparatively abundantly on the coast, but becomes rarer and less productive towards its southern limit.

In Norway the southernmost record of the species is only slightly further north than the corresponding locality in Sweden, 60°45′ N latitude. However, in a large part of its Norwegian area it is much rarer than in Sweden, being fairly common only in the arctic part of the country. Here it has long, narrow, rather disconnected areas bordering the upper parts of the fjords. It does not grow in the immediate vicinity of the sea.

In Finland it is distributed throughout the country, with the exception of Ålandia, for which there is no certain record. However, its frequency and berry production vary greatly from one part of Finland to another. It clearly possesses an optimal area, in which it occurs abundantly and fruits more regularly and abundantly than in the remainder of the country. This area comprises North Karelia, North Savo, the north of North Häme, the southwest of North Ostrobothnia, Central Ostrobothnia and part of South Ostrobothnia (Fig. 2). Owing to its habitat requirements, the species does not occur uniformly within this optimal zone, but is found sparsely over rather extensive areas. North and south of this zone, which lies roughly between 62° and 66° N latitude, the species occurs less frequently, although it can be locally common. There its berry production is sporadic and usually meagre, although it flowers abundantly throughout the country (SAASTAMOINEN 1930, LAGERBERG 1939).

2. Habitats

In nature R. *arcticus* occurs most often in bogs with spruce and broad-leaved trees, by the seashore (especially along the Bothnian Bay) in patches of similar swampy woodland or in woods with some grasses and herbs, on stony river- and brooksides, and in grass-herb forests in northern Finland (SAASTAMOINEN 1930).

In addition, some man-made habitats are particularly favoured by the species. It has greatly benefited by ditching and the clearing and burning-over of woodland, and by the maintenance of damp natural meadows originating from half-cleared spruce-broad-leaved tree bogs. The large numbers of clearings and hummocky, water-logged natural meadows in Central Finland have influenced the frequency and abundance of R. *arcticus* in that region. Especially in such areas, its favourite sites are the edges of ditches (SAASTAMOINEN 1930, VAARAMA 1965).

A common feature of the different habitats of R. *arcticus* is the absence of a dense or shady vegetation cover. The species seems to flourish in fairly damp conditions, but is not a hydrophyte and does not even tolerate a very high water table. The soil type of the substrate does not seem to be decisive, although the species avoids heavy clays. A layer of weakly humified litter promotes rapid spreading.

3. Biology

31. Morphology

311. Subterranean parts

The root system of R. *arcticus* was investigated by SAASTAMOINEN (1930). The subterranean part of the stem is generally ca. 3—5 cm long and more or less erect; from its buds arise both shoots and roots. The main part of the subterranean portion of the plant consists of a rootstock, lying at a depth of ca. 3—5 cm, which branches horizontally in all directions and can form buds. From the rootstock small feeder roots grow sideways and downwards. The root system may extend for several metres, and enables R. *arcticus* to spread fairly rapidly, since new shoots arise from the buds on the rootstock (Fig. 3).

The mean thickness of the rootstock is only about 1—1.5 mm. The shoots arise endogenously. They develop most abundantly on the young apical portion of the rootstock. The greatest number of shoots is produced in favourable soil by young vigorous plants. Fewer shoots are developed by weak individuals and older rootstocks. The longer root system excavated by SAASTAMOINEN was 375 cm. Under favourable conditions the rootstock can grow over one metre in one growing season.

312. Aerial parts

The aerial shoots of R. *arcticus* are ca. 10—30 cm long, ascending or erect, herbaceous and annual. The overwintering buds are situated at the soil surface, in the axils of the scale-like lower leaves of the branched, lignified basal part of the shoot. The shoot lacks spines or thorns, the leaves are trifoliate. The middle leaflet is rhomboid, the lower edges of the lateral leaflets are curved, and fairly often develop small lobes. The leaflets are sessile or short-petioled. The petiole of the entire leaf, however, is relatively long. The stipules are often fairly large and elliptical, sometimes nearly round, and persistent. The leaves often

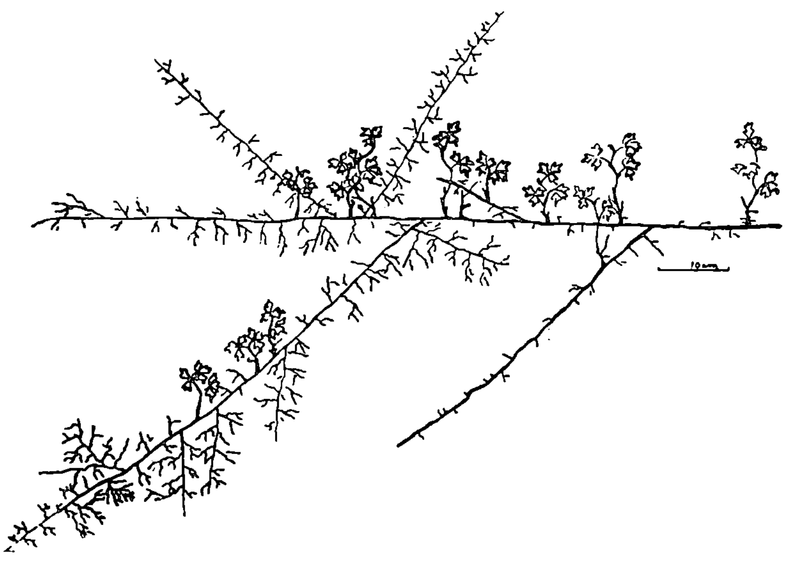


Fig. 3. Root system of R. *arcticus* measuring over 1 m excavated in littoral alder wood. Root in lower right-hand corner old and brittle, remainder of system still vigorous (SAASTAMOINEN 1930).
Kuva 3. Rantalepikosta esille kaivettu yli 1 m pituinen mesimarjan juuristosysteemi. Oikealla alhaalla oleva juuri vanhaa ja haurasta, muu juuristo elinvoimaista

have brownish-red or red anthocyanin pigments, particularly in well-lit habitats. The upper part of the shoot and especially the peduncles have short, generally red, glandular hairs. The stem, and to some extent the leaves are shortly pubescent.

The flowers have long peduncles and are usually single, but also occur in twos or threes, arising from the apex of the shoot or the leaf axils. The petals are large (diameter of flower about 2 cm), broadly ovate or obovate, at first intensely red, generally growing paler on opening. The sepals are acutely lanceolate, soon recurved. Both the calyx and the corolla are most often 6—7 partite. The flowers are bisexual, with many stamens and pistils. Flowering begins at the end of May in South Finland, slightly later further north, and continues throughout the summer.

The completely developed berry comprises 15—30 aggregated, particularly juicy drupelets (stone fruits) and is often dark purple-red with a brown tinge. It has an especially fine spicy aroma. The stones of the drupelets are very hard. The seeds take long to germinate (LAGERBERG 1939, VAARAMA 1965).

LARSSON (1969) compared the berries of the different *Rubus* species with regard to their weight, the number of seeds per berry and their weight, and the proportion of the weight of the berry relating to the seeds.

The berry of R. *chamaemorus* L. (the cloudberry) is largest, almost two and a half times as large as that of R. *arcticus*. Its seeds are large, like those of R. *saxatilis* L. (the stoneberry), but their proportion of the weight of the berry is slightly smaller than in R. *arcticus*. The seeds of R. *idaeus* L. (the raspberry) are the smallest, but their number per berry is greater than in the other species. The percentage of the weight of the berry constituted by the seeds is clearly greatest in the stoneberry, being almost 11.

The vitamin C content of R. *arcticus* is ca. 22—28 mg per 100 g berries (LARSSON 1955 and 1970 b, LEVIN 1961).

The seeds of R. *arcticus* are probably mainly distributed by birds. They germinate in the spring, after having been exposed to the frost throughout the winter. The seeds have germinated without frost treatment under experimental conditions, when they were not allowed to dry at any stage (ERVI et al. 1955, LARSSON 1969).

The cotyledons have short hypocotyls and are ovate and ca. 1.5 × 3.5 mm. The first foliage leaf is simple, cordate and serrate. The second and third foliage leaves are tripartite. In the first year's seedling, the radicle generally seems to be separated by a swelling from the thinner weakly branching main root. The seedling flowers at the end of the second growing season at the earliest (SAASTAMOINEN 1930, Fig. 4).

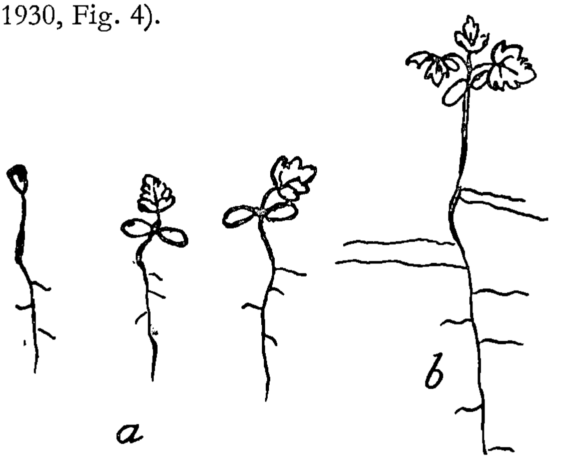


Fig. 4. Seedlings of R. *arcticus* a) at beginning of summer, b) later in the same summer (SAASTAMOINEN 1930).
Kuva 4. Mesimarjan siementaimia a) kesän alussa, b) myöhemmin samana kesänä.

	wt of berry mg	No. of seeds per berry	wt of single seed mg	seed wt per berry mg	seed wt as % of berry
R. arcticus	1019	29	2.659	77.11	7.6
R. chamaemorus	2490	18	8.168	147.02	5.9
R. idaeus	724	34	1.645	55.93	7.7
R. saxatilis	280	3	9.825	29.48	10.9

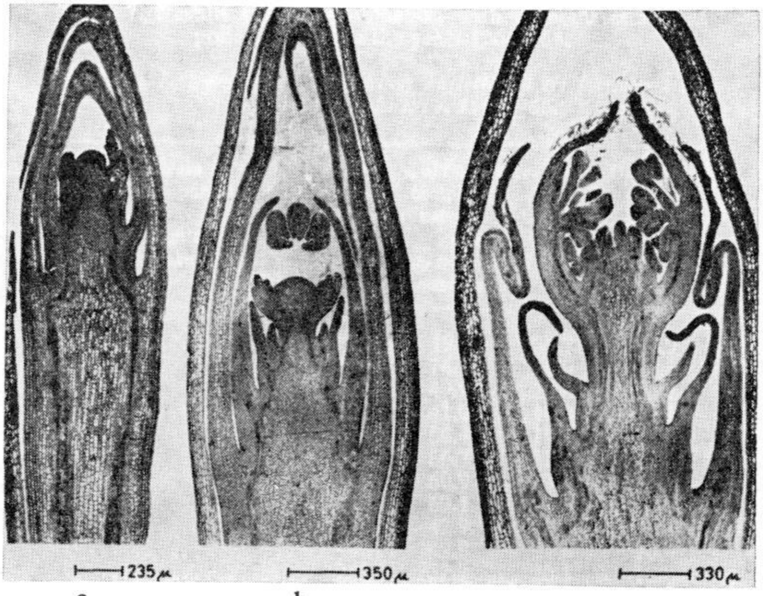


Fig. 5. Development at Viik (ca. 60° N lat.) of floral organs of R. *arcticus* strain originating from Maaninka. a)beginning of differentiation of floral organs on 6. VIII 1962, b) beginning of differentiation of stamens on 13. VIII 1962 and c) archespor formation stage and beginning of differentiation of carpels on 25. VIII 1962 (ZELLER 1964).

Kuva 5. Mesimarjan kukka-aiheen kehitys Viikissä (n. 60° pohj. lev.) Maaningalta peräisin olevalla kannalla. Kuvassa a) kukka-aiheen erilaistuminen alussa 6. VIII 1962, b) heteitten erilaistuminen alussa 13. VIII 1962 ja c) siitepöly alkuemosoluasteella ja emilehtien erilaistuminen alussa 25. VIII 1962.

32. Development of the floral organs

ZELLER (1964) examined the development of the floral organs of R. *arcticus* in Finland. The differentiation of the floral organs began in the subterranean buds between the middle of July and the commencement of August. The subsequent development of the floral organs was particularly rapid. By the beginning of September all the floral organs had already differentiated being on average at the archesporium stage (Fig. 5). In Lapland differentiation began in the buds at the end of the period of continuous daylight.

In weakly fruiting individuals, 3—6 flowers developed from the overwintering buds and, in addition, 1—3-flowered inflorescences arose from the axillary buds of the shoots which withered in the autumn. In abundantly fruiting plants, the buds contained 1 or 2—3 rudimentary flowers.

33. Spreading

According to SAASTAMOINEN (1930), the rapid establishment of R. *arcticus* in cut-over and burnt-over areas, meadow clearings and sites similarly disturbed by human activity is primarily attributable to its rapid vegetative reproduction. R. *arcticus* is probably already present in some places in these sites, and when the ground is cleared, its rapidly growing rootstock enables it to take swift possession of the area. SAASTAMOINEN reports that she found seedlings of R. *arcticus* only on bare, or almost bare ground. When they grew among other vegetation, they died at the initial stage. Thus distribution by seed is presumably slight compared with vegetative reproduction.

LARSSON (1955) suggests that the sudden appearance of R. *arcticus* in newly cleared areas might be at least partly attributable to the fact that the species occurred in the site a long time ago, and the thick-coated seeds lying deep in the soil retained their viability for a considerable period, starting to germinate when the opportunity arose. In burnt-over areas the heat perhaps has the effect of a "shock treatment" that wakens the seeds to life.

4. Factors affecting distribution and fruiting

The decrease of R. *arcticus* in nature has attracted general attention. The spread and increase in intensity of agricultural activity is considered to be the chief cause. Up to the end of last century, the burning-over of woodland for cultivation, which was universally practised throughout Finland, but especially in Savo and Carelia, created suitable habitats, with reduced competition, for R. *arcticus*. Although the species was forced to give way when stronger competitors arrived in the site, the continued burning-over created further living space for it. In recent decades the intensification of agricultural and forestry activity, and the spread of human settlement have caused a great decline in R. *arcticus*, even within its optimal area, so that its berries have become almost scarce. Outside the optimal area the growth and fruiting of the species have been adversely affected by the vigorous competition offered by the species-rich natural vegetation and also by the scarcity of favourable habitats, such as littoral alder belts, suitable swampy forests and peatland meadows (ERVI at al. 1955).

SAASTAMOINEN (1930) considered that the poor yield of R. *arcticus* may possibly be attributable to the general thermal conditions: the length of the growing period, the average summer temperature and the annual temperature amplitude. In the optimal area of R. *arcticus*, these meteorological values are as follows: length of growing period 7 months, average summer temperature +12 °C and annual temperature amplitude 24 °C. Excessive heat, especially in the middle of the summer, can cause the flowers to dry up before fertilization, and a damp substrate does not seem to eliminate this danger. Presumably the summer temperature south and southwest of the optimal area is generally excessively high for the fruiting of R. *arcticus*, whereas to the north of the area it is too low.

KOTILAINEN (1949) also claimed that excessive insolation at the height of summer may dry up a large part of the flowers of R. *arcticus*. This accords with the fact that the berries are comparatively abundant beside large bodies of water and on large islands. Moreover, frosts seldom occur during the growing season in lakeside habitats, so that the flowers of early summer, which are generally abundant, can also develop fruit.

According to ČERNOVA (1959), temperatures of 2—5 °C, which often prevail during the flowering maximum of R. *arcticus*, are sufficiently low to have a harmful effect on the germination of the pollen and cause darkening of the stigmas.

SAASTAMOINEN further considered that the nature of the snow-lie influences the performance and berry yield of R. *arcticus*. In the optimal area a thick snow cover prevents the species from commencing growth and flowering too early in the spring, and protects it from cold spells. Soil moisture also affects the berry yield, since R. *arcticus* needs a comparatively damp substrate in order to fruit well. As regards its requirements for light, it can fruit abundantly in fairly exposed meadows with a low field layer, among fairly dense grass communities and in rather shady littoral alder belts. All these habitats have sufficient light, at least at the beginning of the summer.

R. *arcticus* has an endotrophic mycorrhiza, which probably does not exert any direct effect on its fruiting (ERVI et al. 1955). However, it does play an important role in improving the absorption of nutrients by the roots, so that conditions which promote the development of mycorrhiza also promote the success of R. *arcticus* (Černova 1959).

Ervi et al. (1955) analysed soil samples from R. *arcticus* localities with both good and poor berry yields. The soil of the localities with good yields clearly had higher contents of P, Cu, Zn and Mn than that of the localities with poor yields. The latter localities had somewhat higher contents of Ca and K, and a slightly higher pH than the localities with good yield.

5. Cultivation experiments with R. arcticus

Linné (Linnaeus 1762) performed cultivation experiments with R. *arcticus* in the 18th century, in the garden of the Department of Botany of the University of Uppsala, and reported that they were successful. The most important of his instructions was that the cultivation area should be covered for the winter with moss and fresh conifer branches, so that the snow would not melt too early in the spring.

The instructions for the cultivation of various berries given by Lindgren and Ringius (1868) include advice on the care of R. *arcticus*. They considered it important to fertilize the substrate with various organic substances (cow manure, urine, decayed sawdust and leaves) mixed in different ways. They also advocated covering the plants carefully with branches of spruce to retain the snow cover.

Saastamoinen (1930) reports that Mr. H. A. Elfving undertook a cultivation experiment with R. *arcticus* at Tervo in North Savo, but we are not told whether it was successful. Saastamoinen herself performed some small experiments, but they lasted only a few years, so that the results were limited. One of her suggestions is that the cultivation of R. *arcticus* should be restricted to its optimal area. She further consideres that R. *arcticus* would probably benefit by dead branches spread out over the substrate. These would both fertilize and lighten the soil, and would help to prolong the snow-lie. They would also provide some shade, and possibly affect the freezing of the ground to the advantage of R. *arcticus*.

In the USSR, the first cultivation experiments with wild berry-bearing plants, including R. *arcticus*, was commenced in autumn 1934, in an area comprising altogether 40 ares, in the Kivač Nature Reserve, in Karelia (62° N lat.). The berry yield reported for R. *arcticus* for 1937 was 530 g/4 m , or 13.3 kg/are. The plants were set out at intervals of 25 cm. Thinning proved necessary once the crop had covered the whole area, about three years later. The best time for planting was found to be the spring (Freindling 1949).

In cultivation experiments performed with R. *arcticus* in the years 1949—54, Černova (1959) observed that phosphate and potassium fertilizers were particularly important for the fruiting of R. *arcticus*. In contrast, the effect of nitrogen was not remarkable. The highest yield, 33 kg/are, was obtained in 1954 from a plot (2.1 m^2) having received phosphate and potassium. The yield from unfertilized plots at the same time was ca. 5.5 kg/are. Černova also found it advantageous to cover the rows and the spaces between the rows with a thick layer of sphagnum moss, and to water the plants during the hottest weather (+30 °C). She gives the maximum weight of a single berry as 1.76 g, the berry being collected in nature.

Ervi et al. (1955) also performed experiments connected with the cultivation of the species, although they were mainly intended to improve conditions in natural habitats. Ground was cleared in a peatland meadow containing R. *arcticus* by digging furrows of different widths to depths of 20 and 40 cm. The results were fairly poor. Other species displaced R. *arcticus* rather rapidly in the cleared places, and it failed to establish itself at all in the deeper furrows. The lower limit of the root system of R. *arcticus* has been observed to lie between depths of 20 and 40 cm.

Ervi et al. believe that a rapid expansion of R. *arcticus* might be achieved by ploughing drills, which would not damage its root system. The fruiting stage of the plant might also be prolonged with suitable fertilizers and soil-improving substances.

Larsson (1955) suggests that the pH of the soil should be low for R. *arcticus*, ca. 4—5. Ammonium sulphate and potassium sulphate should be used as fertilizers, each at the rate of ca. 1 kg/are. Phosphate is probably not needed. Fertilizers should be applied in the autumn, since the delicate buds might be damaged if they were applied in the spring (Larsson 1970).

Between 1948 and 1968, Larsson (1970) carried out research on the wild northern *Rubus* species at the Horticultural Research Station at Öjebyn in Sweden. Her chief aim was to impart the fine flavour of R. *arcticus* to easily cultivated, productive and disease-resistant *Rubus* species by means of hybridization. Promising results were obtained at both the diploid and tetraploid levels by crossing R. *arcticus* and R. *stellatus*, and at the tetraploid level by crossing R. *arcticus* and R. *idaeus*. All these *Rubus* species have the diploid chromosome number $2n = 14$. Larsson found that R. *arcticus* and R. *stellatus*, and the hybrids derived from them did not set fruit when the flowers were isolated at the bud stage. The same observation was made in respect of R. *arcticus* by Freindling (1949) and Černova (1959).

Cross-breeding with R. *arcticus* and R. *idaeus* has also been performed at Piikkiö, at the Department of Horticulture of the Agricultural Research Centre, and has already resulted in some promising individuals (Hiirsalmi 1969).

III INVESTIGATIONS PERFORMED AT THE NORTH SAVO AGRICULTURAL EXPERIMENT STATION BETWEEN 1933 AND 1970

1. Experimental conditions

11. Topography, soil type and nutrient status of experimental areas

The experiments relating to this study were performed at the North Savo Agricultural Experiment Station, at Halola in Maaninka, mainly in two areas: area I was situated in the garden of the experimental station and area II on the so-called 'rantapelto' (shore field).

Area I was on land sloping gently downwards to Lake Maaninka, which lay at a distance of 100 m. The exposure was west-southwest. The area was surrounded by abundant plantations of trees. A high spruce hedge grew along its upper limit and elsewhere it was bordered by pines, mountain ashes, apple trees, etc. There was also a house to the north of the area, so that it was rather well protected from cold winds. Several colonies of bees were in the neighbourhood of the area.

Area II lay to the north of the central buildings of the station, at about the same distance from the lake shore as area I. It was exposed to the wind on all sides. The terrain was even.

In both areas the grain size of the soil varied within the limits of fine sand. An investigation of soil fertility gave the following average results:

Area I: pH 5.7, Ca 1300, K 150, P 12, Mg 120 mg/l and conductivity 0.6 (1966).
Area II: pH 6.1, Ca 1500, K 190, P 17.5, Mg 140 mg/l and conductivity 0.4 (1970).

12. *Meteorological conditions*

Table 1. Temperature and precipitation of the growing period (May—September) in the years 1935—70 at the North Savo Experiment Station. The figures for the individual years are the amounts by which their values deviate from the means for the years 1931—60.

Taulukko 1. Lämpötila ja sademäärä kasvukuukausina (touko—syys) vuosina 1935—70 Pohjois-Savon koeasemalla. Luvut ovat poikkeamia vuosien 1931—60 keskiarvoista Pohjois-Savon koeasemalla.

Year *Vuosi*	Temperature *Lämpötila* °C	Precipitation *Sademäärä* mm	Year *Vuosi*	Temperature *Lämpötila* °C	Precipitation *Sademäärä* mm
1931—60	12.5	281.0	1931—60	12.5	281.0
1935	— 1.3	+ 2.6	1953	+ 0.1	+ 52.2
1936	+ 1.3	— 9.1	1954	+ 0.6	+ 79.4
1937	+ 2.0	+ 8.1	1955	— 0.5	— 84.0
1938	+ 1.1	— 23.6	1956	— 1.2	— 39.1
1939	+ 0.2	— 45.3	1957	— 0.7	+ 67.7
1940	+ 0.6	— 7.7	1958	— 1.0	— 40.1
1941	— 0.3	— 72.6	1959	— 0.2	— 44.6
1942	— 0.5	— 16.1	1960	+ 1.1	— 67.4
1943	+ 0.4	+ 93.4	1961	+ 0.1	+ 44.9
1944	— 0.7	— 37.9	1962	— 1.9	+ 47.0
1945	— 0.2	— 63.0	1963	+ 0.8	+ 66.9
1946	+ 0.5	+ 84.7	1964	— 0.8	+ 6.1
1947	+ 1.2	— 78.7	1965	— 1.0	+ 12.7
1948	+ 0.3	+ 68.7	1966	— 0.3	+ 7.5
1949	± 0.0	— 19.6	1967	+ 0.1	+118.0
1950	— 0.3	— 36.9	1968	— 0.9	— 10.0
1951	— 0.3	— 81.7	1969	— 0.4	— 97.0
1952	— 1.3	+ 75.5	1970	+ 0.2	+ 52.0

2. Material

The *R. arcticus* plants transferred to the experimental field in autumn 1933 were a mixed population obtained from the vicinity of the station. Obvious differences were observed between the different individuals in respect of the luxuriance and colour of the foliage, the abundance, size and colour of the flowers and the berries, etc. In 1935 representatives of the four most clearly defined types were chosen from this mixed population for future experiments.

These four types were designated H/A, H/B, H/C and H/D, and may be characterized as follows:

H/A: Not very luxuriant, leaves dark, flowers rather pale. Fruiting abundant, fruiting percentage ca. 55. Berries red or mottled with red and fairly large.

H/B: Tall-growing, luxuriant, leaves pale, flowers dark. Flowering abundant, fruiting percentage 30—35. Berries most often dark red and of medium size.

H/C: Very luxuriant, sturdy with dark leaves. Flowers pale, large. Flowering abundant, but fruiting % only ca. 25. Berries large, red, reddish or pale greenish.

H/D: A very low-growing, slender type. Leaves and flowers pale. Flowering sparser than in the preceding types and fruiting showing an even greater relative decrease, fruiting % 10—15. Berries pale greenish, sometimes reddish, medium-sized.

From 1960 onwards material of *R. arcticus* was brought to the experimental station from different parts of Finland. The origins of the material are shown below, the comments of the sender being given in inverted commas:

Ap: Rovaniemi, the Arctic Circle Agricultural Experiment Station Apukka. Several plants"not all taken from the same patch, since occurrences were so small".

H/A, H/B, H/C and H/D: The strains used in the earlier experiments.

H/L: Maaninka, Halola. Taken straight from nature for each experiment.

Hä: Hämeenkyrö, the Osara estate. "The plants were growing very far apart and can scarcely represent the same individual."

Le: Lepaa. "The plants were scattered around the same stump."

Lu: Lumijoki. Newly cleared area, about 4 ha in extent, near the Prokkola farm. The individuals used in pollination experiments were marked Lu/A and Lu/B.

Ma: Marttila. Not the same clone.

My: Mynämäki. Not the same clone.

Pa: Paimio. Not the same clone.

P: Piikkiö, Department of Horticulture. Plants "from one stand on the side of a ditch."

T: Tikkurila. "Taken from the same place, at intervals of about 2 m, from a small open place in a spruce-birch forest with shallow peat layer."

T_2: Tikkurila. "From edge of a ditch in peatland."

T_3: Rekola, the same kind of habitat as the preceding.

49—1a and 49—3a: Autotetraploid plants obtained in 1966 from G. Larsson in Sweden.

3. Experimental procedure and treatment of the results

Isolation

The mode of growth of R. *arcticus*, described earlier in this study, enables it to spread rapidly from its original site to the surroundings. Accordingly, from 1960 onwards, the experimental plots were isolated from each other by placing ca. 40 cm broad sheets of roofing felt upright in the ground. Later, strong, 0.15—0.20 mm thick plastic sheeting was used instead of the felt.

Planting

Planting was usually performed at the beginning of June. In various experiments, planting was also performed throughout the summer and up till the autumn. The material planted out was taken from growing crops. In the earlier experiments the plants were set out separately with different intervals between the rows and plants. Later the planting material was spread out in a continuous furrow about 15 cm in depth and with one vertical wall, the shoots being separated from each other only as much as was necessary to leave a few centimetres between them. Watering was usually needed.

Covering the soil surface

It proved necessary to cover the soil in order to keep the berries clean. The material used included moss litter, peat, fresh sphagnum moss, sawdust, sand, gravel, light gravel ('Leca'), wood chips, etc.

Weeds

The areas used for the cultivation of R. *arcticus* were generally fairly free from perennial weeds, including quick grass. From 1965 onwards, the open ground around the R. *arcticus* plants, such as the spaces between the rows, was sprayed with paraquat in the year of planting. Individual root weeds were treated with hormone preparation. Weeding was otherwise performed manually.

Protection against birds

It was often difficult to protect the fruiting crop from birds, particularly thrushes. Various methods were tried. The most usual was to have ordinary roofing shingles dangling at the ends of strings at intervals of about one metre throughout the area.

In 1969—70 all the areas in which the berry yield was investigated were covered with nets with a mesh size of 3.5 cm.

Harvesting the berries

The berries were picked at least once a week. The picking season usually began in the first week of July and continued till September, and sometimes even till October. The berries were graded into three groups, the first comprising perfect berries, the second imperfect berries developed from insufficiently pollinated flowers, the third berries which had become overripe or were otherwise spoiled. The weight of the berry was determined on the first group.

Treatment of the results

In the statistical treatment of the results, use was made of the t-test with paired observations, or the analysis of variance. In the latter procedure the STUDENT-NEWMAN-KEUL test was employed (STEEL and TORRIE 1960).

4. Results

41. The biology of R. *arcticus*

411. The root system and the spread of the individual

In summer 1970 soil profiles extending to depths of ca. 30—50 cm were examined in some of the experimental areas by excavating soil sections of a thickness of 10 cm. The sections were taken from R. *arcticus* crops of different ages and from different kinds of soil. The sections were placed on sheets of sieve netting (mesh 9 mm) with another net on top and the soil was rinsed from the root systems. Long nails were passed through both nets to keep the root systems in position. This method was found to function satisfactorily. The root systems were then photographed.

In light soil (Fig. 6 a), the root system extended fairly uniformly to a depth of ca. 30 cm and a good proportion of the roots continued below that level, some reaching depth of over 40 cm. The soil in this case was medium fine sand, and the thickness of the top soil layer was 25—30 cm. The root system thus reached the subsoil, which was also medium fine sand. The area had been planted in 1967.

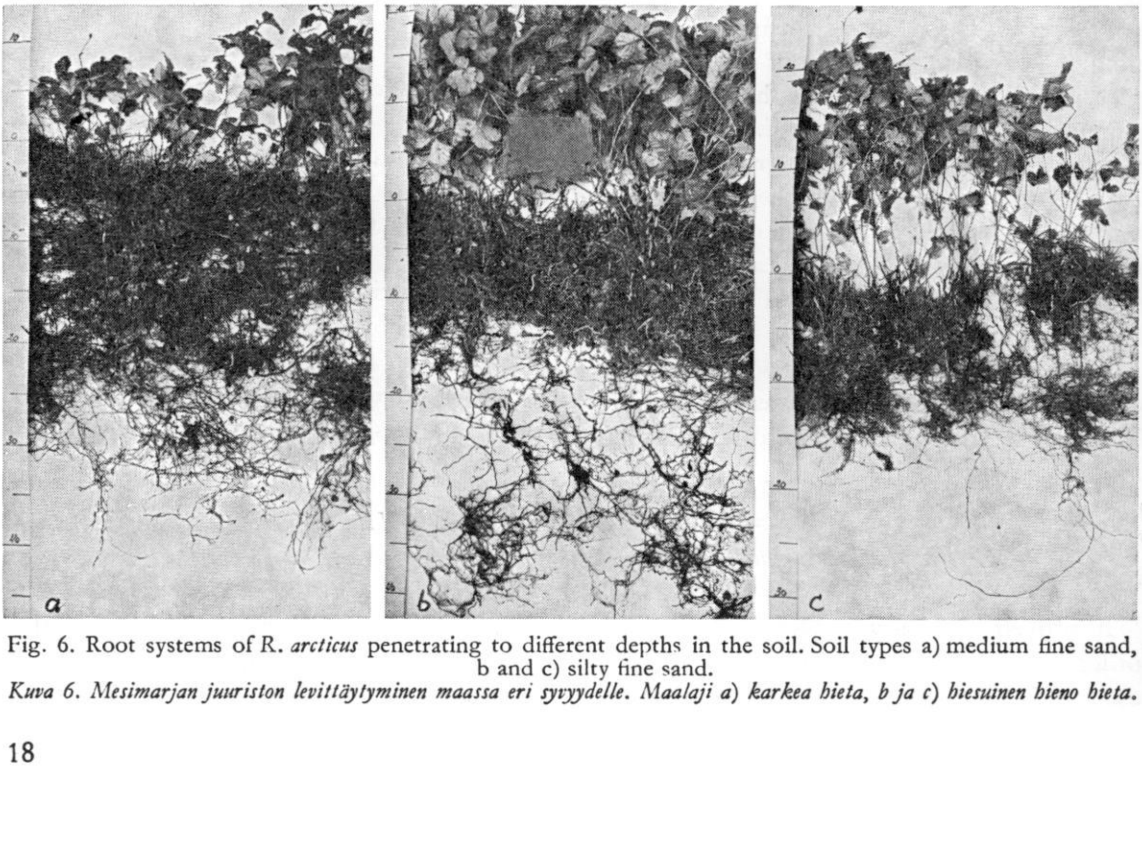


Fig. 6. Root systems of R. *arcticus* penetrating to different depths in the soil. Soil types a) medium fine sand, b and c) silty fine sand.
Kuva 6. Mesimarjan juuriston levittäytyminen maassa eri syvyydelle. Maalaji a) karkea hieta, b ja c) hiesuinen hieno hieta.

In finer-particled soil (Fig. 6 b and c) the greater part of the root system occupied the 0—15 cm layer, only a few of the roots penetrating below this level. In the samples shown in Fig. 6 b and c, the soil was silty fine sand and the thickness of the top soil layer was 45—50 cm. Both samples were taken from areas planted in 1964.

A root system of R. *arcticus* is also shown in Fig. 7.

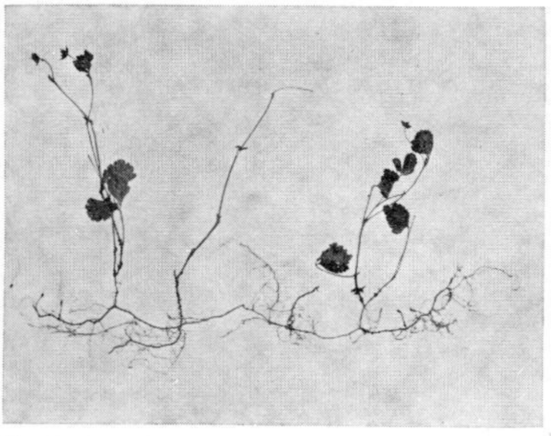


Fig. 7. Part of root system of R. *arcticus*. The shoots have withered and overwintering buds have developed at the tips of the short subterranean stems arising from the horizontal rhizome.
Kuva 7. Mesimarjan juuristoa. Versot ovat jo kuihtuneet ja talvehtimissilmut kehittyneet vaakasuorasta juurakosta kasvaneiden lyhyiden maanalaisten varsien päihin.

The mode and the rapidity of the spreading of R. *arcticus* individuals was examined in an experiment commenced in spring 1964 (28. V). Plots measuring 4 m × 4 m were isolated with sheets of roofing felt extending down to the subsoil, and a single two-branched plant of R. *arcticus* was placed in the centre of each plot. The plants were of the Le and P strains; there were six replicates and the plots were arranged in two rows with alternating strains. The plots were covered throughout with a 5-cm-thick layer of coarse sand. At first the weeds were destroyed by spraying with paraquat and later by manual weeding.

The individuals formed a roughly circular patch, spreading outwards at the rate of 0.5 m a year, i.e. the diameter of the patch increased by about 1 m a year. In 1968, the fourth year after planting, the edges of the circular patch reached the isolating fences before the end of the growing season. In the following year they filled the corners of the plots. By this time each individual covered about 16 m^2. R. *arcticus* thus spreads rather rapidly. Thanks to its capacity for vigorous vegetative growth, its propagating is rather simple (KALLIO 1971). It can also be propagated by using root cuttings with subterranean shoots (ČERNOVA 1959).

412. The shoot and its development during the growing season

The mode of growth of the shoot was examined in 1966. Fig. 8 shows shoots of strain P. The plant in the bottom left corner

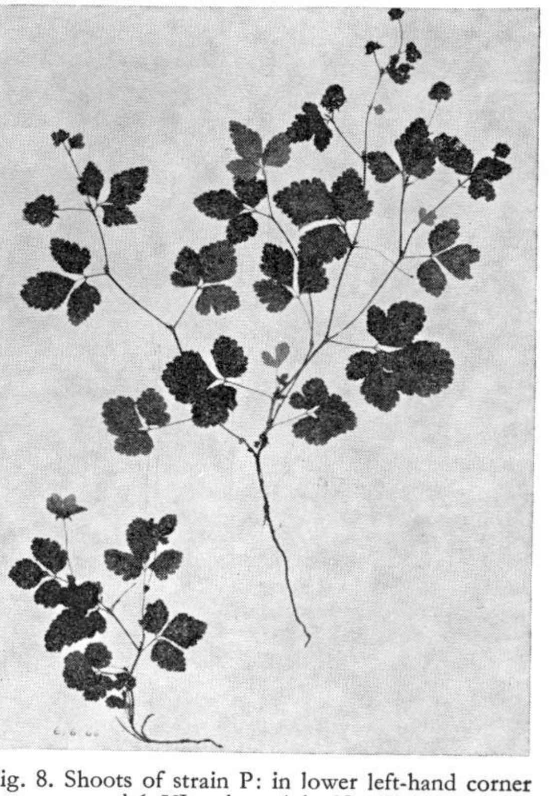


Fig. 8. Shoots of strain P: in lower left-hand corner pressed 6. VI and on right 28. VII 1966.
Kuva 8. P-kannan versoja: vasemmalla alhaalla oleva prässätty 6. VI, oikeanpuoleinen 28. VII 1966.

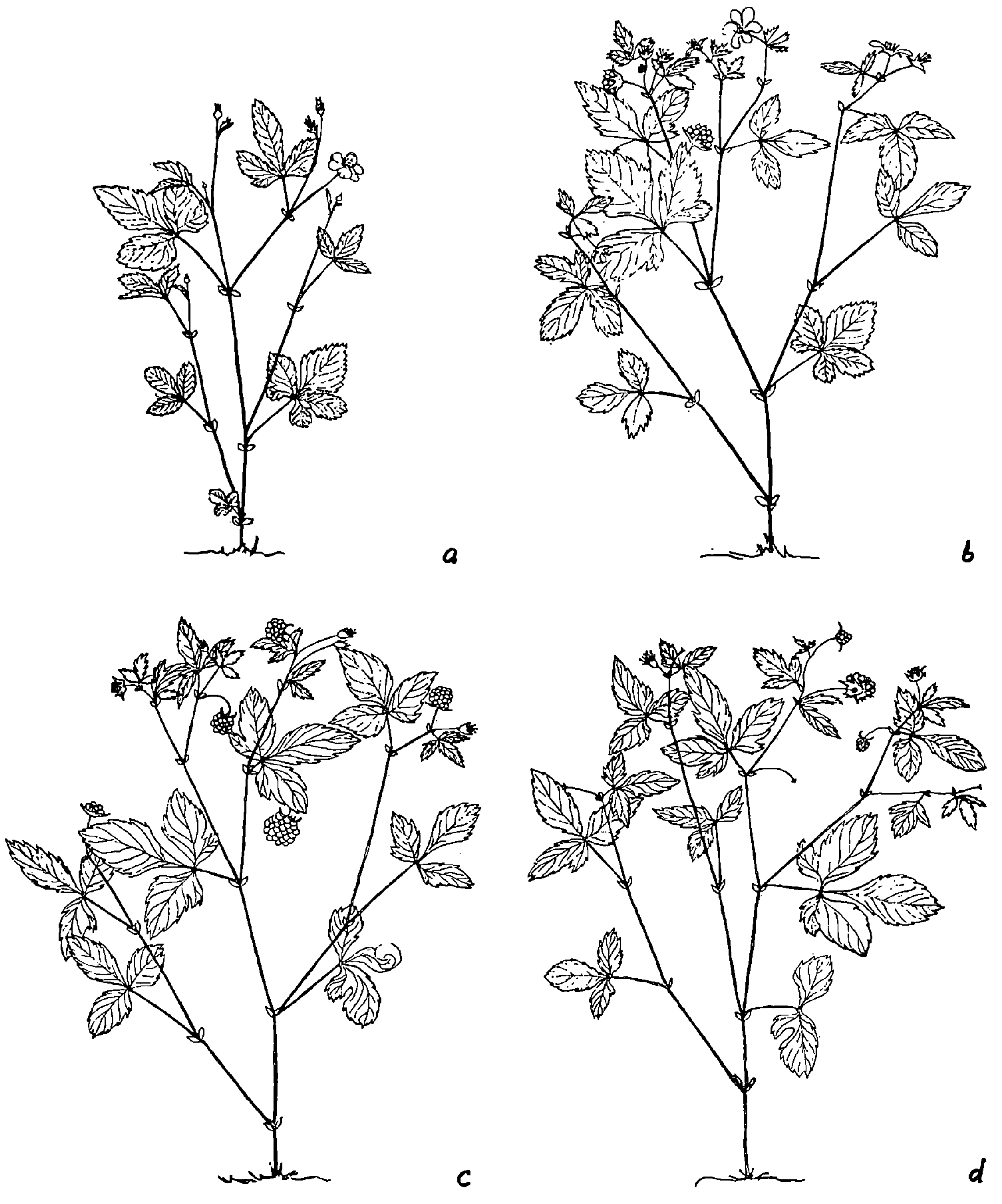


Fig. 9. Shoot of strain Lu a) 10. VI, b) 23. VI, c) 8. VII and d) 22. VII 1966.
Kuva 9. Lu-kannan verso a) 10. VI, b) 23. VI, c) 8. VII ja d) 22. VII 1966.

was pressed on 6. VI (photographed later). By then its height was 12 cm and it already had two branches. The older branch had flowered but the younger had only a bud. The larger shoot system in the figure was pressed on 28. VII. It was abundantly branched with a ripe or immature berry at the tip of each branch. It no longer had any flowers.

Individual shoots were marked in the different strains and their development was followed during the summer of 1966. Drawings were made on the basis of measurements of the different parts of the shoot performed at two-weekly intervals. The measurements were begun on 10. VI. Fig. 9 (a, b, c, d) illustrates the growth of a shoot of strain Lu.

a. 10. VI 1966: The shoot begins to grow in the spring as soon as the snow has melted. It has a bud at its tip. Flowering thus begins fairly early in the spring. The illustrated shoot had already developed branches. One flower was open. There were buds both at the tips of the branches and in the leaf axils.
b. 23. VI: Branching had continued and the shoot had grown otherwise. A large immature berry had developed from the first flower, and the flowers that were previously in bud had shed their petals.
c. 8. VII: Branching had ceased. The berries had developed farther.
d. 22. VII: The same as before. The ripe berries had been picked.

Growth had thus ceased by the middle of the summer, in July, although it generally continues until August. This was presumably due to warm dry weather at the beginning of the summer, which has been found to cause crops to mature earlier than usual.

413. The leaves

The serration of the leaflets of the trifoliate leaves of R. *arcticus* varies between the different strains, and the shape of the leaves also shows some variation (Figs. 10 and 11).

The shape of the leaf can also vary within the same strain to a greater or lesser extent. Nevertheless, the strains may clearly be seen to have their own characteristic leaf features, as is revealed by a comparison of the leaves of strains H/A and P (Fig. 11).

Some measurements were made to elucidate the differences between these two strains on

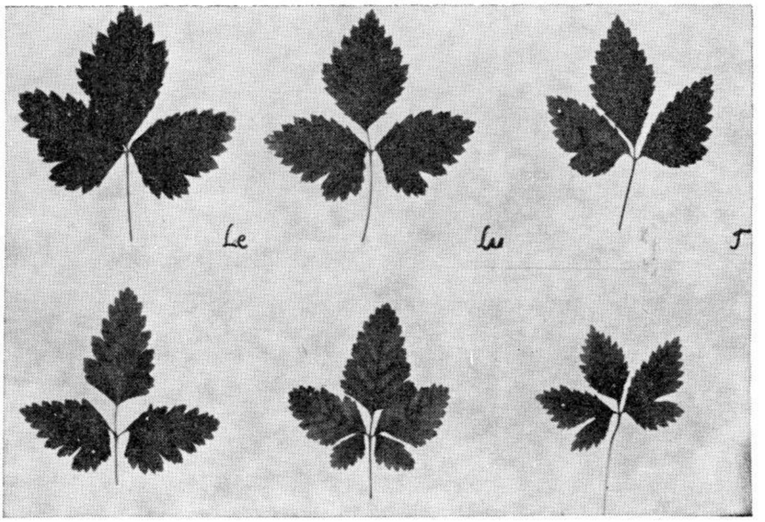


Fig. 10. Upper row: typical leaves of strains Le, Lu and T. Lower row: some divergent leaf types from crosses.
Kuva 10. Ylärivissä Le-, Lu- ja T-kannan lehtien tyypillisiä edustajia. Alarivissä eräitä poikkeavia lehtityyppejä risteytysyksilöistä.

5. VI and 4. VII 1968. Ten leaves of either strain were measured on each date, the leaves each being the largest on the shoot. The results are shown in Table 2.

The leaf length (L) of strain P was significantly greater than that of strain H/A, but the greatest difference lay in the shape of the middle leaflet. The difference between the

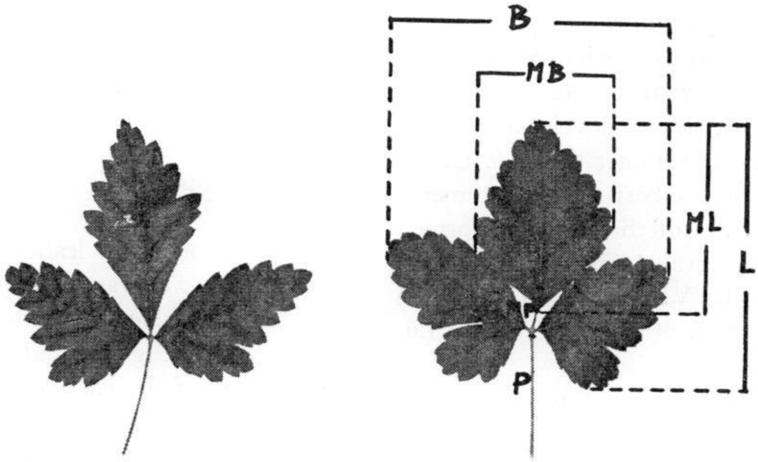


Fig. 11. Leaf of strain H/A on left, leaf of strain P on right.
Kuva 11. H/A-kannan lehti vasemmalla, P-kannan oikealla.

Table 2. Differences between the leaves of strains H/A and P. Measurements performed on 5. VI and 4. VII 1968.

Taulukko 2. H/A- ja P-kannan lehtien erot. Mittaukset suoritettu 5. VI ja 4. VII 1968.

	H/A		P		Significance of differences *Erojen merkitsevyys*	
					Strains	Dates
	5. VI	4. VII	5. VI	4. VII	*Kannat*	*Ajankohdat*
L mm	40.4	50.4	+2.0	+11.5	**	***
B »	47.1	58.1	−0.8	+11.2	ns	***
ML »	34.4	43.4	−5.1	+ 0.4	ns	***
MB »	20.3	24.9	+2.9	+10.1	***	***
MP »	1.4	—	+1.7	—	**	—
P »	19.9	—	+5.1	—	*	—
L/B	0.86	0.87	+0.06	+0.02	ns	ns
ML/MB	1.69	1.74	−0.43	−0.49	***	ns

L = leaf length — *lehden pituus*
B = leaf breadth — *lehden leveys*
ML = leaf breadth — *lehden leveys*
ML = length of middle leaflet — *keskilehdykän pituus*
MB = breadth of middle leaflet — *keskilehdykän leveys*
MP = length of petiolule of middle leaflet — *keskilehdykän ruodin pituus*
P = length of petiole of leaf — *koko lehden ruodin pituus*

Significance of differences:
ns = not significant — *ei merkitsevä*
* $P \leq 0.05$, fairly significant — *melko merkitsevä*
** $P \leq 0.01$, significant — *merkitsevä*
*** $P \leq 0.001$, very significant — *erittäin merkitsevä*

lengths of the middle leaflets (ML) was not significant, but the leaflet breadth (MB) was clearly greater in strain P than in strain H/A, the difference being very significant. The length-to-breadth ratio (ML/MB) of the middle leaflet was thus much smaller in strain P than in strain H/A, reflecting the more rounded shape in the former strain.

Differences were also apparent in the petioles and petiolules (P and MP), which were both significantly longer in strain P than in strain H/A.

The leaves measured on 4. VII were clearly bigger than those measured on 5. VI, but the leaf shape (L/B and ML/MB) was the same.

414. The flowers

R. *arcticus* generally flowers throughout June, July and August, flowering being most abundant in June (Fig. 13 a).

The flower of R. *arcticus* has many carpels in the centre of a cupulate receptacle. The stamens curve towards the centre of the flower, covering the stigmas almost completely. The flower structure suggests that it is self-pollinating (Fig. 13 c).

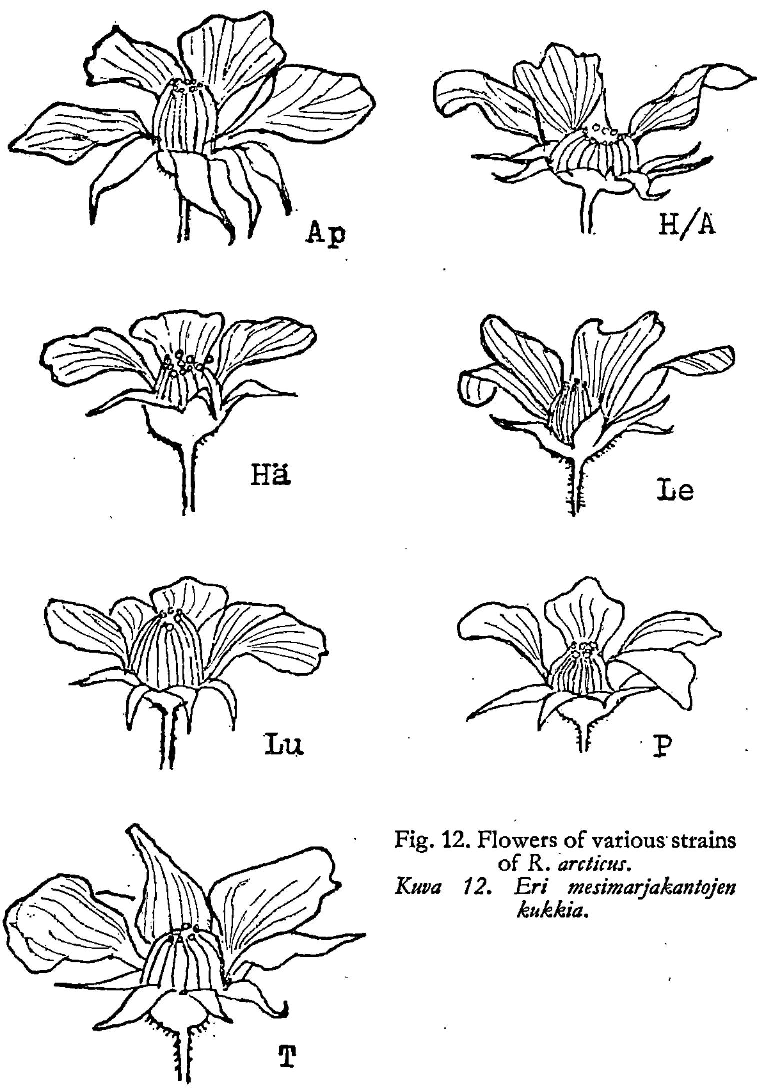


Fig. 12. Flowers of various strains of R. *arcticus*.
Kuva 12. Eri mesimarjakantojen kukkia.

The flowers vary to a greater or lesser degree between the different strains, differing in such features as size, the colour and shape of the different parts of the androecium and the hairiness of the calyx (Fig. 12).

Ap: Flowers large. Anthers small and pale yellow, darkening as they open. Filaments white, fairly broad. Sepals long, sloping obliquely downwards, weakly hairy.
H/A: Flowers fairly large and petals often partly multiple. Many stamens in a broad receptacle. Filaments white or slightly reddish, fairly broad. Anthers pale yellow, fairly large with abundant pollen. Calyx almost glabrous.
Hä: Flowers medium-sized. Anthers with a warm yellow colour, small, filaments fairly broad, white or slightly reddish. Calyx very weakly hairy.
Le: Flowers fairly large. Anthers pale yellow, filaments white, thin and long, pursed up. Sepals long, pointing upwards and densely hairy.
Lu: Flowers fairly large. Anthers with a warm yellow colour, filaments white and fairly broad. Stamens bending towards the pistils and mixed up, one on top of the other. Calyx glabrous. Flowering earlier than the other strains.
P: Flowers medium-sized. Stamens numerous and pursed up. Anthers with a warm yellow colour, their pollen sacs containing abundant pollen. Filaments often reddish. Calyx weakly hairy.
T: Flowers large. Anthers pale yellow, small and not opening until the flower is completely open. Filaments white and thick, bending towards the pistils, so that the anthers are almost invisible. Buds easily detached. Calyx weakly hairy.

The differences between the flowers were studied more closely in an investigation of the flowers of strains H/A and P. The following characters were determined (4. VII 1969) on ten flowers of each strain: number of petals, sepals and carpels, and the diameter of the flower. The diameter was taken as being the greatest distance between the tips of two petals of the flower. The flower was not pressed or spread out.

	H/A	P	Significance of differences
Diameter of flower mm	21.5	20.0	*
No. of sepals	6.6	6.0	*
No. of petals	7.0	6.2	*
No. of carpels	41.8	44.0	ns
range	20—64	33—60	

The flower of strain H/A was fairly significantly larger than that of strain P, and also had more sepals and petals. The difference between the average numbers of carpels was not significant, but the range of variation between the numbers of carpels per flower was smaller in strain P than in strain H/A.

The investigations of strains H/A and P thus revealed fairly clear differences between both the leaves and the flowers, which were even evident from the appearance of the growing crops.

In 1968 the average flower size and number of petals were ascertained by measuring the diameters and counting the petals on 20 flowers of each of 72 individuals of the F_1 generation. An average value of 23.5 mm was obtained for the diameter, the range of variation between individual flowers being 13—36 mm. The range of variation of the average values of the individual plants was 18.6—31.7 mm.

The average number of petals was 6.5, the range of variation between the individual flowers being 4—14. The average values of the individual plants ranged from 5.8 to 8.9.

In about 26 % of the individuals some of the petals had fringed margins. In ten individuals some of the flowers, in one even 60 %, were completely fringed. Emarginate petals occurred in two individuals.

Some difference was also noted between the flower buds of the different strains. In summer 1966 the length and breadth was measured on five buds of each of 12 strains, immediately before they opened (Table 3). The average bud length was 7.6 mm and the breadth 5.4 mm.

Significant differences were found between the strains in respect of bud length, but not in respect of breadth. According to the STUDENT-NEWMAN-KEUL test (STEEL and TORRIE 1960: 110), the greatest bud length, 8.4 mm, strain Le, was significantly ($P \leq 0.01$) greater than the smallest bud length, 6.5 mm, strain P, and fairly significantly ($P \leq 0.05$) greater than the second smallest bud length, 6.9 mm,

Fig. 13 a. R. *arcticus* flowering in June.
Kuva *Mesimarjan kukintaa kesäkuussa.*

b. Fruiting of R. *arcticus* on Leca gravel.
Mesimarjoja Leca-sora alustalla.

c. Cross-section of flower of R. *arcticus.*
Halkaistu mesimarjan kukka.

d. Cross-section of ripe berry of R. *arcticus.*
Halkaistu kypsä mesimarja.

e. Range of colours of ripe berries of R. *arcticus.*
Kypsien mesimarjojen värivaihtelua.

b—e) Photographed by J. Tammisola
Valokuvannut

Table 3. Length and breadth of flower buds of various strains in 1966.

Taulukko 3. Kukkanuppujen pituus ja leveys eri kannoilla v. 1966.

Strain *Kanta*	Length *Pituus* mm	Breadth *Leveys* mm	Strain *Kanta*	Length *Pituus* mm	Breadth *Leveys* mm
Ap	6.9	5.3	Le	8.4	5.1
H/A	7.3	5.6	Lu/A	8.0	5.4
H/B	7.8	5.7	Lu/B	7.4	5.2
H/D	7.9	5.4	P	6.5	5.4
Hä	8.3	5.3	T	7.5	5.4

strain Ap. The differences between the bud lengths of strains Le and P were also statistically fairly significant. The petals of the buds were as long as the sepals in strains H/A, Hä and also often in strain P, but the calyx was longer than the corolla in strains Le and T, among others.

415. Fruiting

a. Pollination in the original natural strains and in the autotetraploid plants

Preliminary experiments to elucidate pollination in R. *arcticus* were undertaken at the North Savo Agricultural Experiment Station in 1940—42. Individuals of the different H strains were isolated in frames made of gauze. Two plants of the same strain, or two plants of different strains were enclosed in the same frame. Plants of each strain were also isolated singly. One or two "clean" bees were enclosed in some of the frames, while others were left without.

The results were partly inconsistent. There were several uncertain features in the arrangement of the experiments. As subterranean partitions were not yet in use, some mixing of the strains may have occurred. It is also possible that the bees were not always completely free of earlier pollen.

However, the results indicated that pollination by a different strain may be important for fruiting. It remained uncertain whether, and to what extent, self-fertile strains are found. SALMINEN (1948) concluded from these experiments that self-fertility does exist, though only to a minor degree.

Experiments on the pollination of R. *arcticus* were continued in the 1960s. Besides the H strains, the material now included plants collected from different parts of Finland. The individuals of the different strains were cultivated in 1.21-m^2 plots separated by subterranean partitions down to a depth of about 40 cm. Above ground, the plots were enclosed in gauze frames provided with one wall of colourless plastic, to improve the illumination, and with removable lids. The frames were placed in position before the commencement of flowering and any insects enclosed in them were killed with DDT or parathion. Before pollination was performed, certain buds were emasculated by removing the calyx, corolla and stamens with one cut of a sharp, thin-bladed knife, or by removing the stamens alone. Pollen was transferred to the stigmas from detached stamens, or by brushing them lightly with the whole of the androecium. Pollination was performed either immediately after emasculation or a few days later.

The results of pollination experiments undertaken in the years 1964—66 are shown in Tables 4—7. Cross-pollination was carried out only between strains originating from different parts of the country. Intraclonal pollination was performed between plants derived from the same individual.

Table 4. Number of flowers fertilized by cross-pollination in the years 1964—66. In parentheses flowers fertilized by intraclonal pollination in 1964—65.

Taulukko 4. Ristipölytettyjen kukkien lukumäärä eri kannoilla v. 1964—66. Sulkeissa intrakloonisesti pölytettyjen kukkien lukumäärä v. 1964—65.

Seed parent *Emikukat*	Pollen parent — *Hedekukat* Ap	H/A	H/D	H/L	Hä	Le	Lu/A	Lu/B	P	T	T_2	T_3	Total *Yht.*
Ap	(11)	—	59	15	41	110	—	—	97	41	13	18	394
H/A	15	(12)	55	15	114	103	—	10	137	52	55	33	589
H/D	13	5	(45)	15	38	64	—	—	42	44	15	36	272
H/L	8	5	55	(13)	51	67	—	—	41	50	18	26	321
Hä	8	80	47	8	(77)	76	20	10	158	45	10	27	489
Le	90	5	55	20	95	(84)	5	5	173	57	27	26	558
Lu/A	—	10	—	—	13	10	(5)	—	73	—	10	—	116
Lu/B	—	10	—	—	17	3	—	(7)	65	—	—	—	95
P	61	101	51	20	187	181	44	80	(105)	59	116	34	934
T	15	5	48	14	45	75	—	—	47	(46)	15	45	309
T_2	5	64	23	5	43	75	—	5	151	25	(15)	13	409
T_3	14	5	28	10	30	47	—	—	26	35	10	(18)	205
Total *Yht.*	229	290	421	122	674	811	69	110	1010	408	289	258	4691 (438)

Table 5. Results of artificial cross-pollination and intraclonal pollination in different R. *arcticus* strains in 1964—65.

Taulukko 5. Eri mesimarjakantojen pölyttyminen ristipölytystä ja intrakloonista keinopölytystä käytettäessä v. 1964—65.

Year and strain *Vuosi ja kanta*	Cross-pollination *Ristipölytys* No. of pollin. flowers *Pölyt. kukkia kpl*	Complete berries % *Täydell. marjoja %*	No berries % *Ei keh. %*	Drup./pollin. flower *Lohkoja/pölyt. kukka kpl*	Intraclonal pollination *Intraklooninen pölytys* No. of pollin. flowers *Pölyt. kukkia kpl*	Complete berries % *Täydell. marjoja %*	No berries % *Ei keh. %*	Drup./pollin. flower *Lohkoja/pölyt. kukka kpl*
1964								
Ap	255	27.1	35.7	5.9	11	0	72.7	1.7
H/A	355	50.7	16.3	12.8	2	0	0	3.0
H/D	272	64.0	15.1	13.8	45	6.7	62.2	1.8
H/L	321	43.0	22.7	8.8	13	0	92.3	0.1
Hä	249	47.0	17.7	10.1	50	24.0	34.0	5.3
Le	310	44.8	22.9	11.1	65	3.1	50.8	1.8
P	342	67.8	11.7	15.4	37	5.4	54.1	2.2
T	309	57.9	18.8	13.1	46	2.2	73.9	0.9
T_2	152	44.7	25.0	9.8	10	0	90.0	0.3
T_3	205	35.1	18.0	7.4	18	0	94.4	0.1
Total/mean *Yht./keskim.*	2770	49.4	19.9	11.2	297	6.7	59.9	2.1
1965								
Ap	30	0	63.3	1.1	—			
H/A	88	70.5	6.8	17.4	10	0	80.0	0.3
Hä	105	43.8	22.9	9.7	27	11.1	48.1	2.1
Le	108	53.7	27.8	10.6	19	10.5	42.1	2.5
Lu/A	56	69.6	12.5	16.1	5	0	100.0	0
Lu/B	50	34.0	18.0	8.0	7	14.3	14.3	3.4
P	196	86.7	3.1	20.8	68	0	95.6	0.1
T_2	117	69.2	8.6	13.6	5	0	20.0	1.6
Total/mean *Yht./keskim.*	750	63.1	14.8	14.3	141	4.3	71.6	1.0
1964—65	3520	52.3	18.8	11.8	438	5.9	63.7	1.7

Table 6. Results of artificial cross-pollination and spontaneous self-pollination in different R. *arcticus* strains in 1966.

Taulukko 6. Eri mesimarjakantojen pölyttyminen ristipölytystä käytettäessä sekä itsepölytyksen tapahtuessa v. 1966.

Strain	No. of pollin. flowers	Cross-pollination Complete berries %	No berries %	Drupelets/ pollin. flower	Self-pollination No. of berries	Drupelets/ berry
		Ristipölytys			*Itsepölytys*	
Kanta	*Pölyt. kukkia kpl*	*Täydell. marjoja %*	*Ei keh. %*	*Lohkoja/ pölyt. kukka kpl*	*Marjoja kpl*	*Lohkoja/ marja kpl*
Ap	109	18.3	51.4	4.0	9	1.7
H/A	146	43.8	21.2	10.0	17	2.2
Hä	135	42.2	18.5	9.1	99	1.7
Le	140	23.6	41.4	5.5	61	2.4
Lu/A	60	51.7	33.3	8.9	23	2.0
Lu/B	45	26.7	15.6	6.5	4	2.3
P	396	61.4	15.9	13.3	82	2.3
T_2	140	42.9	20.7	8.8	26	1.5
Total/mean *Yht./keskim.*	1171	44.4	24.7	9.6	321	2.0

Cross-pollination experiments were continued in 1966. In addition, berries resulting from self-pollination were collected from individuals kept in isolation. The results are shown in Table 6.

The berries considered to be fully formed in Tables 5 and 6 were those containing 10 drupelets or more. Such berries have a normal appearance. Gaps are generally evident in berries with a smaller number of drupelets.

According to the results, R. *arcticus* is self-sterile, although this sterility is not entirely complete. When intraclonal (1964—65) or self-pollination (1966) occurred, the flower developed an average number of ca. two drupelets. In the cross-pollination experiments the average numbers of drupelets in the different years ranged from 10 to 14.

When intraclonal pollination was performed in 1964 (Table 5), strain Hä formed the greatest number of drupelets per pollinated flower. This was presumably due to the fact that the plants of this strain did not all originate from the same individual (see p. 16). When pollination was carried out within one plant of this strain in 1965, the average number of drupelets per pollinated flower was only 2.1. The corresponding value for self-pollinated Hä plants in 1966 was 1.7. These results indicate that the plants of Hä were as self-sterile as the other strains used in the experiments.

After intraclonal pollination in 1965, Lu/B had slightly more drupelets per flower (only seven flowers pollinated) than the other strains, whereas in the cross-pollination experiments its fertilization was rather poor. The reason for this is unknown.

The most productive strains in the cross-pollination experiments were P and H/A. The least productive was Ap. It was used comparatively frequently as a pollen parent in the cross-pollinations. Since its pollinating qualities were also poor (cf. Table 7), it reduced the average productivity of the other strains.

In addition to differing in fertility as seed parents, both when pollinated with their own pollen and in cross-pollination experiments, the different strains of R. *arcticus* revealed clear differences in respect of the effect of their pollen (Table 7). Strain H/A proved to be the best pollinator, and Lu/A, Lu/B and H/B were also fairly good. Strain Ap was clearly poorer than the others.

Table 7. Results of cross-pollination with different strains as pollen parents in the years 1964—66.

Taulukko 7. Marjojen muodostuminen käytettäessä eri kantojen siitepölyä ristipölytyksissä v. 1964—66.

Strain Pollen parent *Kanta* *Hedekukat*	No. of pollin. flowers *Pölyt. kukkia kpl*	% of flowers developing complete berries *Kukista % täydellisiä marjoja*	no berries *ei kehitt.*	Drupelets/ pollin. flower *Lohkoja/ pölyt. kukka kpl*
Ap	229	19.7	39.7	4.9
H/A	290	74.1	6.9	16.3
H/D	421	49.9	20.4	10.2
H/L	122	41.0	18.0	9.1
Hä	674	56.4	19.7	13.0
Le	811	56.7	17.4	12.8
Lu/A	69	60.9	17.4	14.1
Lu/B	110	69.1	7.3	14.6
P	1010	42.9	22.3	10.1
T	408	42.9	21.6	10.4
T_2	289	52.9	20.1	12.0
T_3	258	34.9	26.0	7.7
Total/mean *Yht./keskim.*	4691	50.3	20.3	11.3

The autotetraploid plants 49—1a and 49—3a were also tested to ascertain whether they were self-sterile. Both clones proved to be in some degree self-fertile. The number of drupelets per berry admittedly failed to reach the normal diploid level, but the clones may possibly have had a smaller number of pistils. When they were fertilized with their own pollen the average numbers of drupelets were as follows:

49—1a: $\bar{x} = 7.4 \pm 1.8$, $n = 17$
49—3a: $\bar{x} = 5.4 \pm 0.9$, $n = 16$

The number of drupelets per berry rose only slightly when cross-pollination was performed, the average being 10.0 in 49—1a and 8.0 in 49—3a.

b. The type of self-sterility in R. *arcticus*

Self-sterility was studied in R. *arcticus* in 1968—69 (TAMMISOLA and RYYNÄNEN 1970). The period during which the mechanism of self-sterility is operative was investigated by pollinating flowers of strain P with pollen from the same individual 24 hours before they were pollinated with pollen from another strain (Le). The mean number of growing ovaries formed per flower was then roughly the same as when normal cross-pollination was performed with the other strain. Thus self-sterility is operative in R. *arcticus* before karyogamy, and is due to incompatibility.

This incompatibility was investigated further by examining pollination in the F_1 generation. The material was limited to 13 individuals derived in 1965 from reciprocal crosses of the original P and H/A strains. On the basis of the results from the pollination experiments, the population could be divided into four equivalence classes, comprising individuals displaying the same incompatibility relations. The individuals in these classes numbered 1, 2, 4 and 6.

When the results of each intraclonal pollination were compared with those of the other intraclass pollinations of the same seed parent, fertility was found to be lower in the intraclonal pollinations.

One member of each of the equivalence classes of the F_1 generation was fertilized with pollen from both parents. The parents were able to fertilize all the classes completely, and did not belong to any of them. Since earlier results (Table 5, p. 28) had shown that both parents were self-sterile, but cross-fertile, they do not belong to the same equivalence class.

The incompatibility in R. *arcticus* seems to be of the sporophytic-gametophytic type, with sporophytic control in the style and gametophytic control in the pollen. This type of incompatibility system has been encountered in earlier studies in all the members of *Rosaceae* found to be self-sterile (ARASU 1968).

The results of these pollinations revealed that at least five incompatibility alleles are involved.

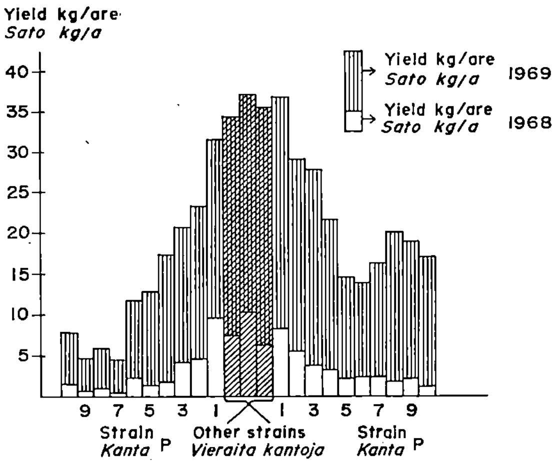


Fig. 14. Yields of R. *arcticus* at various distances from other strains in 1968—69.
Kuva 14. Mesimarjasadot eri etäisyyksillä vieraista kannoista 1968—69.

c. Significance for pollination of the proximity of another strain

From the practical point of view, the availability of pollen of another strain proved to be necessary for the fruiting of R. *arcticus*. The main pollinating agents are bumble-bees and honey-bees. The anatomy of the flower is such that smaller insects have difficulty in reaching its nectar.

Unless disturbed, bumble-bees and honey-bees generally keep to nearby flowers in the same flowering stand, when changing from one flower to another. In spring 1967, an experiment was undertaken to elucidate the significance for pollination of the proximity of different strains. Three rows of plants of different strains were set out at 1-m intervals in the centre of the experimental area. On either side of them were set out ten similarly spaced rows of plants of strain P. The berries of each row were picked separately in the years 1968 and 1969, and the yields are shown in Fig. 14.

The height of the columns shows clearly that the proximity of another strain is of vital importance for fruiting. A distance of 2 m clearly decreased the yield as compared with 1 m, and at a distance of 4 m the yield was only half that at a distance of 1 m. Fruiting generally grew weaker with distance from the other strains.

The yields of the rows on the left side of the figure are clearly poorer than those on the right side. The reason for this is evidently that there were no R. *arcticus* plants growing on that side, whereas on the right side R. *arcticus* was growing at a distance of about 10 m from the outermost row. In spite of the distance, this possibly had a favourable effect on the outer experimental rows, since there were no flowering plants in between. However, the yields of these outer rows were fairly poor.

This question was also studied in another way in summer 1968. Quadrats with an area of 0.1 m^2 were marked out in crops of strain P at distances of 1, 5 and 10 m from the plants of the other strains growing in the middle rows. All the flowers and berries developing within the quadrats were counted throughout the summer (Fig. 15).

The results were in complete agreement with those of the previous experiment. The formation of perfect berries improved with proximity to the other strains.

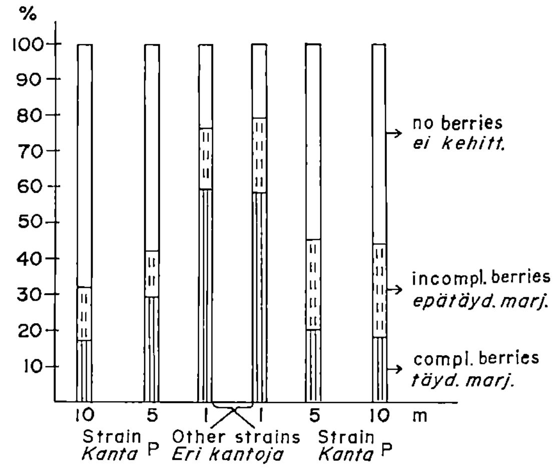


Fig. 15. Percentages of flowers of strain P producing complete and incomplete berries and failing to set fruit in 1968 at distances of 1, 5 and 10 m from other strains.
Kuva 15. Täydelliset ja epätäydelliset marjat sekä kehittymättä jääneet kukat %:eina kukkien kokonaisluvusta 1, 5 ja 10 m:n etäisyydellä vieraista kannoista kasvaneella P-kannalla 1968.

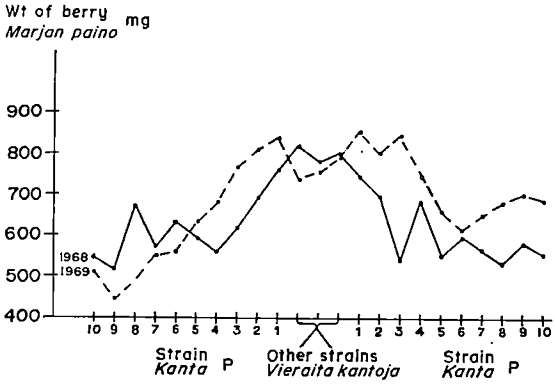


Fig. 16. Weights of berry in yields obtained from strain P growing at different distances from other strains in 1968—69.
Kuva 16. Marjan painot eri etäisyyksillä vieraista kannoista kasvaneen P-kannan sadoissa 1968—69.

Besides the amount of the berry yield, the weight of the berries was also found to be influenced by the distance from the other strains (Fig. 16).

Although the weight of the berry was determined on so-called "perfect" berries, which contained at least ten drupelets, the size of the berries showed a fairly clear tendency to decrease towards the outermost rows. Pollination evidently became less complete, so that a smaller number of ovaries were fertilized and the average weight of the berry decreased with the number of drupelets.

d. Significance for pollination of bumble-bees and honey-bees

The significance of bumble-bees and honey-bees for the fruiting of R. *arcticus* was investigated in an experiment performed in1969. Before the commencement of flowering, plants of strains H/A and P were isolated together in four enclosures made of netting with a mesh size of 3 mm. Quadrats of 0.1 m² were marked out both inside and outside the enclosures. The flowers within these quadrats were marked and counted and the development of the berries was followed.

No. of marked flowers		% of flowers developing perfect berries	imperfect berries	no berries
Inside nets	583	4.6	22.5	72.9
Outside nets	564	74.3	11.9	13.8

Smallish flies were generally found within the nets, but no bumble-bees or honey-bees.

The activity of large pollinating insects was found to be one of the conditions of normal fruiting in R. *arcticus*. The insects able to pass through a 3-mm-mesh net were too small to be efficient pollinating agents. About 73 % of the flowers inside the nets failed to set fruit, whereas the corresponding value outside the nets was only ca. 14.

e. Dehiscence of the anthers and duration of fertility of the carpel

From the point of view of the pollination of R. *arcticus*, it is important to know how long the flower remains susceptible of pollination. An attempt was made to obtain this information by finding out at what stage of the flower's development the pollen is fully formed, i.e. when the anthers dehisce, and how long the carpel continues to be fertile.

Dehiscence of the anthers. — The dehiscence of the anthers was examined in strain Le on 19. VI 1968, and the following observations were made on the stamens and pollen in buds at different stages of development:

Petals visible only when viewed directly from above:
anthers completely closed, pollen not visible.

Petals showing slightly between sepals:
anthers closed, pollen not visible.

Calyx slightly opened:
anthers closed, pollen not visible (emasculation stage).

Petals still completely folded:
anthers closed, only a few in process of dehiscing, i.e. pollen visible in sutures, a little pollen on a few of the stigmas.

Petals still folded, but flower opening within one day:
half of anthers dehisced, abundant pollen, a few grains here and there on the stigmas.

Flower just opening:
the lowermost anthers closed, the uppermost already turning brown, abundant pollen, especially on the middlemost stigmas.

Flower just opened:
the lowermost anthers still closed, the uppermost old and brown, a little pollen on the stigmas.

The pollen was thus fully formed at a fairly early stage of the development of the flower. It was most abundant when the petals were still folded but soon about to open. When the flower had opened completely the pollen had already largely deteriorated.

Duration of fertility of the carpel. — The duration of the fertility of the carpel was examined in 1967 and 1968. On 4. VIII 1967, buds of strains H/A and P were isolated in perforated parchment bags. The anthers of these buds had still not dehisced, or were just on the point of dehiscing. The stamens were not removed until required for pollination. The strains had earlier been found to be self-sterile.

Period between isolation and pollination (days)	Stage of development of flower	No. of pollinated flowers	No. of flowers setting fruit
Strain H/A			
0	Bud	3	3
1	Flower open, outermost anthers open.	2	2
2	As before. Pollen yellow.	2	2
3	Stamens grown beyond stigmas. Pollen brownish yellow.	3	3
4	As above.	2	2
5	As above. Flower ageing.	2	2
6	a) Stigmas green.	1	1
	b) Some of stigmas brown.	1	1 imperfect
7	a) Stigmas green.	1	1
	b) Stigmas moist, some brown.	1	0
8	Many of stigmas brown.	2	0
9	Stigmas brown.	2	0
Strain P			
0	Bud.	2	2
1	Flower open. Outermost anthers open. Pollen yellow.	5	5
2	Petals somewhat withered or fallen. Anthers grown beyond stigmas. Pollen light yellow.	2	2
3	Pollen faded yellow.	2	2
4	Pollen greyish yellow.	3	3
5	As above.	2	2
6	Flower ageing, stigmas brown	3	1
7	Stigmas moist.	2	0
8	a) some stigmas green.	2	0
	b) Stigmas moist and brown.	2	0

The carpels were still fertile in both strains, although the flowers had clearly aged and the pollen had deteriorated. The duration of complete fertility after the opening of the flower was ca. six days in strain H/A and five days in strain P.

On 27. VI 1968, buds of strain Le were emasculated and isolated in gauze bags at a stage at which they might be expected to open after three days.

At the same time buds of plants of strain P growing inside the net enclosures were isolated without being emasculated. The buds chosen were those expected to open the following day.

Two flowers of each of the strains were pollinated at intervals of one day.

Period between isolation and pollination (days)	Flowers setting fruit Le (emasculated)	 P (not emasculated)
1	2	2
2	2	1 (reason unknown)
3	2	2
4	2 imperfect	2
5	2 one imperfect	2
6	0	2
7	0	1
8	0	0
9	0	0

Although the flowers of strain Le were pollinated at an earlier stage of their development than those of strain P, their fertility terminated earlier. Fruiting was already imperfect on the fourth day after emasculation. The duration of fertility was presumably shortened by emasculation. The fertility of the flowers of strain P remained unimpaired for six days. They had not been emasculated, and in addition they had been better protected from sun and wind, being enveloped in a gauze bag within a net enclosure.

f. The abundance of flowering and the development of the berries af different times in the growing season and under different weather conditions.

A comparative experiment was commenced with the different strains of R. *arcticus* in 1964 (area of each strain 56 m²). In summer 1966 this material was examined to ascertain the percentages of the flowers setting fruit. From 6. VI onwards, a hundred flowers were marked in each plot at two-weekly intervals, with different-coloured tape. The strains were H/A, Le, Lu, P/h and P/N. The P plots differed in that the plot of P/h was covered with sand, while that of P/N was covered with sphagnum moss, like the other plots in this investigation.

Fruiting showed two clear peaks in all the strains, except Le. The first peak related to the flowers marked on 20. VI, the second to those marked on 18. VII and 1. VIII (Fig. 17).

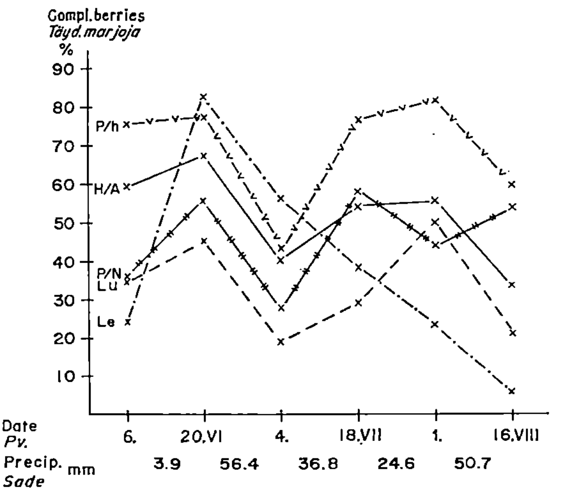


Fig. 17. Amounts of complete berries (%) produced by flowers of different strains marked on certain dates. Below, precipitation (mm) in intervals between marking dates.

Kuva 17. Täydellisten marjojen prosenttimäärä kunakin merkitsemispäivänä 1966 merkityistä eri kantojen kukista. Päivämäärien alla sademäärät (mm) merkitsemispäivien välillä.

In 1966 the beginning of the summer was warm and dry, while the middle and the later parts were cool. The beginning and end of July were rainy. The pollination of the flowers marked on 4. VII was presumably disturbed by the rainy weather. The weather was fine around 18. VII and 1. VIII, which would favour pollination.

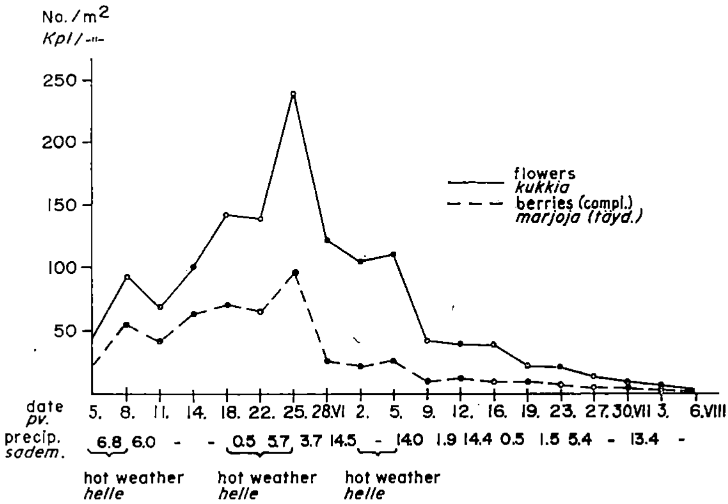


Fig. 18. Numbers of flowers and complete berries per 1 m² in period 5. VI—6. VIII 1968. Below, precipitation in intervals between marking dates, and hot periods.

Kuva 18. Kukkien ja täydellisten marjojen lukumäärä 1 m²:ä kohti ajalla 5. VI—6. VIII 1968. Päivämäärien alla sademäärät (mm) merkitsemispäivien väliaikoina sekä merkinnät hellekausista.

In 1968, the abundance of flowering and the development of berries were examined at different times in the growing season. Altogether thirty 0.1-m² quadrats were marked out among the different strains. At intervals of three to four days, all the open flowers in these quadrats were marked and counted and the ripe berries were picked. The abundance of the flowers and of the fruit set by them showed one clear peak, relating to the flowers opening around midsummer (Fig. 18).

In 1968 the growing season was noticeably cooler than average, with the exception of June, and fairly dry, with the exception of May. Although flowering and fruiting showed a clear peak around midsummer, even then only a comparatively small proportion of the flowers set fruit. In June the weather was hot and precipitation low. The average number of flowers developing per m² during the whole observation period was 1350.

Fruiting was also followed in different strains in summer 1970. Ten flowers that were just opening were marked in each of the following strains: H/A, Le, Lu and P. Strain P was growing in two different experimental

Table 8. Time elapsing between opening of flower and ripening of berry, fruiting %, weight of berry and number of seeds per berry in various strains in 1970.

Taulukko 8. Kukan avautumisesta marjan kypsymiseen kulunut aika sekä marjomis-%, marjan paino ja siementen lukumäärä marjassa eri kannoilla v. 1970.

Strain *Kanta*	Ripening time days *Kypsymisaika vrk*	Fruiting % *Marjomis-%*	Wt of berry *Marjan paino mg*	Seeds/berry *Siemeniä/marja kpl*
H/A	35	60	750	25
Le	37	50	430	15
Lu	37	60	710	24
P_1	37	70	710	27
P_2	36	68	830	32

areas, designed P_1 and P_2. Strains H/A and P_1 were planted out in 1967, and were growing in moss-covered plots; the other strains were planted out in 1968, the plots being covered with Leca gravel.

Flowers were marked at the beginning of flowering on 6—8. VI, and from then onwards at two-weekly intervals. The ripe berries were weighed and the number of seeds counted. The results are shown in Table 8.

The time required for the berries to ripen was almost the same in all the strains, 35—37 days. The fruiting percentage in the P strain was about 10 units higher than in strains H/A and Lu. The berries of strain P also had more seeds (= drupelets) than the other strains. Strain Le was the poorest in all respects. The results were affected by the very unfavourable conditions for pollination prevailing in July (cf. Table 9).

The combined results of this experiment were used to determine the average development of the berries at different times in the growing season of 1970. The development of the berries was clearly influenced by the time of flowering and the weather conditions (Table 9).

The berries ripened most rapidly in June, within 33—34 days. The fruiting percentages, weights of the berries and the numbers of seeds were also high, indicating that conditions were favourable for fruiting. June was warm with low precipitation.

The berries clearly took longer to ripen in July, 36—39 days, and the fruiting percentages were particularly low, only 30. The berries were also small and the numbers of seeds were low. The precipitation of July was noticeably high, more than twice as high as normal, and the fact that pollinating insects are not in flight in rainy weather would be sufficient to impair fruiting.

The berries took even longer to ripen in August than in July, but the fruiting percentage and the size of the berry were better than in the previous month, although they were not as good as in June. The weather had become cooler, retarding ripening, but the precipitation had decreased and pollination thus improved.

The time required for the berries to ripen was also studied in artificially pollinated plants of different strains in the years 1964—66 (Table 10).

The average ripening time was about five weeks in 1964 and 1966. Summer 1965 was cool and rainy, and in that year the time required for ripening was slightly longer, 38 days.

The time taken by the berry to ripen varied somewhat between the strains, but no particularly clear trend could be noted in the differences, except that the berries of strain Ap,

Table 9. Time required for ripening of berries, fruiting %, weight of berry and number of seeds per berry at different times in the growing season in 1970.

Taulukko 9. Marjojen kypsymiseen kulunut aika, marjomis-%, marjan paino ja siementen lukumäärä marjassa kasvukauden eri aikoina v. 1970.

Flowers marked on *Kukat merkitty*	Ripening time days *Kypsymis-aika vrk*	Fruiting % *Marjomis-%*	Wt of berry mg *Marjan paino mg*	Seeds/ berry *Siemeniä/ marja kpl*
8. VI	33	80	880	35
22. VI	34	80	970	36
6. VII	39	30	370	17
20. VII	36	30	370	10
3. VIII	42	52	660	22

Table 10. Time elapsing between artificial cross-pollination and ripening of berries in various strains growing in gauze enclosures in 1964—66.

Taulukko 10. Keinopölytyksestä (ristipölytys) marjojen kypsymiseen kulunut aika eri kannoilla harsokangashäkeillä suojatuissa kasvustoissa v. 1964—66.

Strain (seed parent)	1964			1965			1966		
Strain (seed parent) *Kanta (emikukat)*	No. of pollin flowers *Pölyt. kukkia kpl*	No. of berries *Marjoja kpl*	Ripening time days *Kyps. aika vrk*	No. of pollin. flowers *Pölyt. kukkia kpl*	No. of berries *Marjoja kpl*	Ripening time days *Kyps. aika vrk*	No. of pollin. flowers *Pölyt. kpl*	No. of berries *Marjoja kpl*	Ripening time days *Kyps. aika vrk*
Ap	209	128	32	30	11	36	109	53	32
H/A	287	243	34	68	62	39	121	98	35
H/D	206	174	34	—			—		
Hä	204	169	34	95	74	37	135	110	33
Le	247	189	36	93	71	37	140	82	32
Lu/A	—			46	41	37	60	40	34
P	268	238	35	135	130	40	281	239	36
T	235	201	36	—			—		
Total/mean *Yht./keskim.*	1656	1342	35	467	389	38	846	622	34

which came from the northernmost area, ripened slightly more rapidly than those of the other strains.

g. Capacity of the flowers to tolerate frost

R. arcticus begins to flower fairly early in the spring, so that it is liable to be damaged by the frosts that are common throughout Finland in the spring and early summer. The capacity of the flowers to withstand cold was examined in 1967, when several frosts occurred, and in 1970.

Experiment I. — On 2. VI 1967, flowering plants of *R. arcticus* growing in three plastic sheeting pots were transported to a bog, where the temperature was expected to fall below freezing-point the following night. Flowers at different stages of development were marked with different-coloured tape: old, young and just opening. A minimum thermometer showed that on the night preceding 3. VI the temperature sank to —2.6 °C. The pots were subsequently transferred to a frame where they could be protected from any later frosts.

The marked flowers were not damaged by the frost and each developed normal berries.

Experiment II. — On 12. VI 1967, new flowering plants were transported to the bog in three similar pots. All the already opened flowers were removed so that only the opening buds were left. On the night preceding 13. VI the temperature sank to —2.7 °C. It also sank to —1.0 °C on the night preceding 15. VI. The pots were not removed till 15. VI.

These frosts caused permanent damage to the carpels of the flowers in one of the pots. They only partly damaged the flowers in the other two, since they were able to develop berries, though they were not perfect.

Experiment III. — On 6. VI 1967, flowers on plants growing in the garden of the experimental station were marked with different-coloured tape, as in experiment I. On the night preceding 7. VI, the temperature sank to —3.1 °C.

The stamens and carpels were not damaged. The days preceding the night of frost, and that following it were cold and rainy.

In 1970 similar experiments were performed in a natural stand growing in the bog. It was found that the flowers were destroyed when the temperature sank below —4.0 °C.

It was also noted in these experiments that the flowers which were just opening were more susceptible to damage than those which were already open. The stamens clearly tolerated cold better than the carpels.

416. The berries

In the aggregate fruit of *R. arcticus* each drupelet contains one seed. The receptacle remains in a cavity within the swollen ovaries, to which it is organically connected (Fig. 13 d p. 25). Thus the base of the berry is very tightly attached to it and cannot be removed without the berry being broken.

The berries of certain strains were examined in 1967, attention being paid to their size, the number of seeds, the weight of the seeds and the drupelets, and the proportion of the weight of the berry relating to the calyx and the seeds (Table 11).

The berries of strain P proved to be best from the economic point of view, since their weight was greatest and the proportion relating to the calyx and seeds was smallest (7.87 %).

The berries of strain Le had almost the same weight as those of strain P, but the seeds were larger and the proportion of the weight of the berry relating to them and the calyx was greater than in all the other strains (9.72 %).

The berries of strain Hä were particularly small. The number of drupelets was low and the weight of the individual drupelets was clearly smaller than in the other strains.

It may be mentioned here that, when all the experimental areas and years are taken into account, the largest berries weighed over 4 g, the weight of the very largest being 4.6 g. The greatest number of drupelets observed in a berry was 101, the weight of this berry being 4.35 g.

The colour of the berries varied noticeably between the different strains, and even within the same strain. The colour often does not indicate the degree of maturity. A completely immature berry may be red throughout, and a completely ripe berry may lack the red colour entirely, being yellowish or greenish. The berries were often mottled red (Fig. 13 e, p. 25).

Table 11. Weight of berry, number of seeds per berry, weights of seed and drupelet and proportion of berry weight relating to seeds and calyx in various strains in 1967. Means of 200 berries given for strains H/A and P, means of 100 berries for the other strains.

Taulukko 11. Marjan paino, siementen lukumäärä marjassa, siemenen ja lohkon paino sekä siementen ja verhiön osuus marjan painosta eräillä kannoilla v. 1967. Luvut ovat H/A- ja P-kannasta 200 marjan, muista 100 marjan keskiarvoja.

Strain / *Kanta*	Wt of berry mg / *Marjan paino mg*	Seeds/ berry / *Siem./ marja kpl*	Wt of seed mg / *Siemenen paino mg*	Wt of drupelet mg / *Lohkon paino mg*	% of weight of berry — *Marjassa p-%* seeds / *siem.*	calyx / *verhiö*	together / *yht.*	Rel. value / *Suhdeluku*
H/A	990	26.6	2.06	37.3	5,50	3,11	8.61	100
Hä	560	18.3	1.69	30.6	5.54	3.26	8.80	102
Le	1010	25.4	2.26	39.8	5.69	4.03	9.72	113
P	1090	33.5	1.75	32.6	5.37	2.50	7.87	91
Mean *Keskim.*	913	26.0	1.94	35.1	5.53	3.22	8.75	

The extent of the red colour in the berry seemed to depend to some degree on the amount of insolation received, but more on some property of the strain. The berries of strain P were generally bright red throughout. The red of the berries of strain H/A was of a slightly dull shade.

417. The seeds, their germination and the seedlings

The seeds. — The seed proper of *R. arcticus* lies within a bone-hard pericarp, which has the shape of a slightly curved ellipse, and is rough-surfaced and light in colour. The inside of the seed is filled with gelatinous endosperm. (Fig. 19).

The size of the seeds (with pericarp) varied considerably between the strains (Tables 11, p. 38, and 28, p. 58). The average individual weights of the seeds of strains P and Le shown in Fig. 19 were 1.55 mg and 2.05 mg, respectively.

Germination. — The germination of the seeds was studied when large amounts of berries were obtained from the pollination experiments, and F_1 plants were required. The berries were allowed to dry in open cardboard boxes at room temperature. Before sowing, the seeds were separated from each other by hand. The germinating seeds were subjected to cold treatment.

Seeds obtained from the pollination experiments performed in 1965 were put to germinate on 12. X 1965 in 'Jiffy' pots, of the size 8×8 cm. The pots were filled with sand and fertilized 'Finn-humus peat' mixed in the ratio of 2 : 1. Twenty-five seeds were sown on the surface of each pot, or less if this number was not available. They were covered with a few millimetres of fine sand and watered. The pots were covered with plastic and left at room temperature for three days, after which they were taken out to a plant-frame where they were left uncovered throughout the winter. The seedlings were counted in June (Table 12).

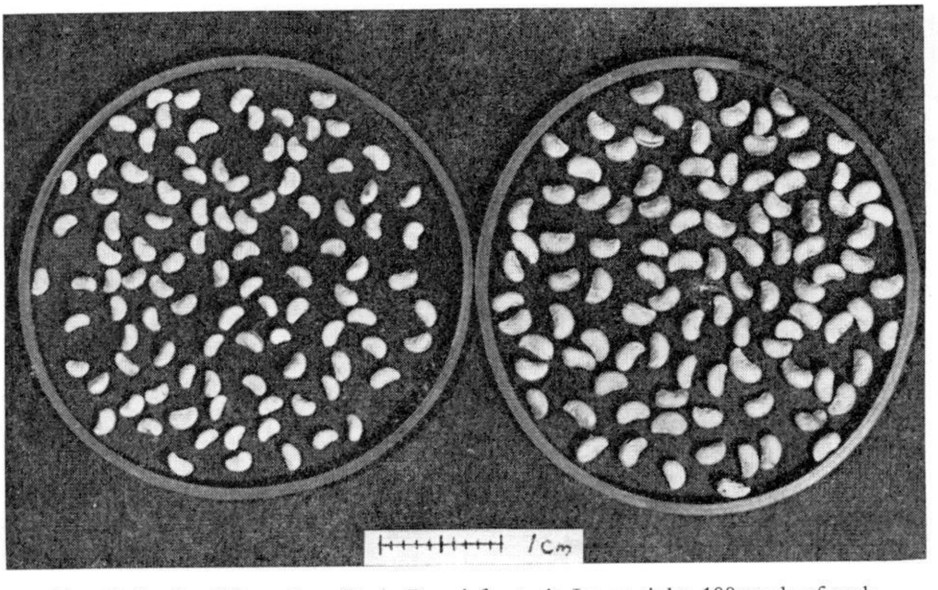


Fig. 19. Seeds of *R. arcticus*. Strain P on left, strain Le on right, 100 seeds of each.
Kuva 19. Mesimarjan siemeniä. Vasemmalla P-kannan, oikealla Le-kannan siemeniä, molempia 100 kpl.

Table 12. Germination of seeds of R. *arcticus* after intraclonal and cross-pollination.

Taulukko 12. Mesimarjan siementen itäminen. Pölytys suoritettu sekä oman että vieraan kannan siitepölyllä.

Strain (seed parent) *Kanta (emikukat)*	Intraclonal pollination *Pölytetty omalla kannalla*		Cross-pollination *Pölytetty vieraalla kannalla*	
	No. of seeds *Siemeniä kpl*	Seedling % *Taimett. %*	No. of seeds *Siemeniä kpl*	Seedling % *Taimett. %*
H/A	4	0	216	52.3
Hä	66	36.4	254	40.6
Le	79	7.6	207	23.7
Lu	22	18.2	233	69.5
P	12	25.0	350	22.9
Total/mean *Yht./keskim.*	183	20.2	1260	40.2

Of the seeds obtained from cross-pollination, on an average, 40 % germinated (developed into seedlings), whereas the corresponding value for the seeds obtained from intraclonal pollination was only ca. 20 %. Large differences existed between the different strains. The seeds that clearly germinated best were those obtained from strain Lu when it was pollinated with another strain. Strains Le and P were the poorest germinators. Seeds obtained from pollination within the same strain actually germinated slightly better in strain P, and almost as well in strain Hä, as seeds obtained from pollination with another strain.

Seeds obtained by cross-pollination in 1967 were germinated in earthernware pots. The substrate was the same as before. The seeds were not sown until the later part of the winter, on 1. III 1968. The pots were covered with plastic and kept at room temperature for one wee, before being taken out to the frame. The following percentages developed into seedlings:

Strain (seed parent)	No. of seeds	Seedling %
H/A	70	78.6
Hä	21	90.5
Le	14	28.6
P	158	67.7

The percentages were clearly higher than those shown in Table 12, but there were great differences between the strains.

The seeds of strain Hä germinated best, 90.5 % developing into seedlings. The number of seeds from strain P was much greater than those from the other strains, and they also germinated comparatively well. Strain Le again proved to be a weak germinator.

T h e s e e d l i n g s. — The first stage in the development of the seedlings of R. *arcticus* has already been described (Fig. 4, p. 11). As it was desired to raise plants for research, the seedlings were transplanted from the germination pots in the spring to individual peat pots, in which they were left to grow all that summer in the frame. In the early summer of the following year each seedling was transplanted to its own 1-m^2 plot, with subterranean partitions, in the experimental field. Ca. two years later the plant covered 70—80 % of the area of the plot.

The seedlings generally began to flower and fruit towards the end of the summer in which they were transplanted to the field. Seedlings growing among other plants and receiving no special care develop more slowly.

The most important results of the biological study of R. *arcticus* reported above are: For all practical purposes, the plant is self-sterile. Thus at least two different strains are needed for a berry yield. The main pollinating agents are bumble-bees and honey-bees. The different strains should be planted close to each other, if optimal cross-pollination is to be achieved.

42. *The cultivation of* R. *arcticus*

421. Type of substrate and acidity of soil

T y p e o f s u b s t r a t e. — In the cultivation experiments performed for this study at the North Savo station, the substrates were fine sand soils having rather favourable moisture properties. In some of the experiments the soil was coarser fine sand, but in most of them it was very fine sand or silty fine sand, and thus fairly heavy. R. *arcticus* did well on all these soils.

R. *arcticus* was grown on various types of soils in cultivation experiments begun in 1970 in different parts of Finland. These showed that it even did excellently on sandy silt (Ylistaro). A rather heavy soil can be prevented from becoming too hard by covering the surface.

The suitability of a peat substrate was also examined. An experiment with different strains of R. *arcticus* (experiment VII, p. 51) was begun on drained peatland in 1957. Initial growth was rapid and the plants at first appeared to be doing well. However, in the following years they clearly ceased to thrive and their berry yields were low. This was probably due to insufficient moisture. The soil surface was not covered.

In 1964 R. *arcticus* was planted in fertilized 'Finn-humus' peat. The thickness of the peat layer was about 20 cm. The plants developed abundant shoots and very few berries There were also indications of some illness (mildew) in the shoots.

This tendency of peat to induce excessively abundant shoot formation was observed on various other occasions, and can be put to use for plant propagation. Even though the influence of very peaty soil on the berry yield appeared unfavourable, peat can be used to lighten excessively heavy soils or to increase the water-retaining capacity of rapidly draining substrates.

A c i d i t y o f s o i l. — In nature R. *arcticus* most usually grows in localities where the soil is comparatively acid. The experimental areas at the North Savo Agricultural Experiment Station were in the best fields, where the pH was around 6; for example, the pH was 5.9 in the experimental plot that in 1963 produced the then record yield of 96 kg/are. Since it appeared that R. *arcticus* can flourish in soils of widely varying acidity, an experiment was arranged with a view to elucidating the significance of the pH of the substrate.

The experiment was carried out with pails filled with the following soils:

1. pH 3.20 alum clay from the 20—50 cm layer (Jurva, Tainusjärvi)
2. pH 3.63 alum clay from the plough layer (Jurva, Tainusjärvi)
3. pH 3.82 muddy clay from below the plough layer (Ylistaro)
4. pH 3.89 muddy clay from below the plough layer (Ylistaro)
5. pH 5.03 loose soil-litter from pastured forest with R. *arcticus* (Halola)
6. pH 5.41 very fine sand (Halola)

Twelve-litre plastic pails with perforated bottoms were filled with the soils, three being used for each soil type. On 4. VII 1967, plants of strain P were planted in each pail. The soil surface was covered with moss and the pails were sunk in the ground, with an underlying, ca. 5-cm layer of sand.

The development of the plants was followed, but the berry yield was not weighed. Initial growth was slower in soils 1—4 than

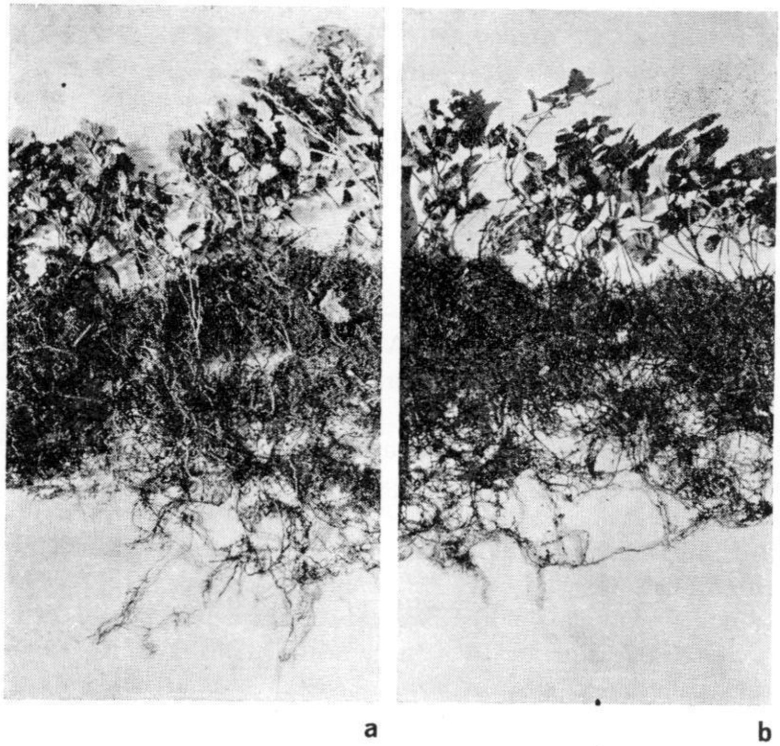


Fig. 20. Plants grown on substrates of different acidity: pH a) 3.63 and b) 5.41.
Kuva 20. Kasvualustan happamuuskokeen kasvustoja. Kasvualustan pH a) 3.63 ja b) 5.41.

in soils 5—6, but when the plants had taken root, the rate of growth was the same in all the soils.

The experiment was ended in autumn 1970. A pail with each soil type was taken for examination. The soil was rinsed from the roots by the method described earlier in the section on the root system (p. 18) and the specimens were photographed (Fig. 20).

Both the root and shoot systems were found to be roughly the same in all the soils. Since the highest pH value of the soils was 5.41, the information obtained from this experiment was somewhat limited, but it did indicate that R. *arcticus* can tolerate very acid soils.

Since experiments performed in the field showed that R. *arcticus* grows and fruits well, e.g. in soil with a pH of 6.35, it may be concluded that the degree of acidity of the substrate is not of great significance for the species.

422. Time and method of planting

T i m e o f p l a n t i n g. — At the North Savo station, R. *arcticus* was planted at almost all times in the growing season, and always started to grow. However, the early summer, when growth is most vigorous, is presumably the best time for planting, provided care is taken to protect the plants from the droughts that frequently occur at that time of the year.

When experimental cultivation was commenced in different parts of Finland in 1969, plantings performed towards the beginning of September proved to be unsuccessful. Establishment was poor and a remarkably large number of the plants had to be replaced in the following spring. The reason may be that the development of the overwintering buds was still in progress and was arrested when transplanting accelerated the withering of the shoot. Better results might be obtained if planting is carried out later in the autumn, when the buds are fully developed.

The above observations relate to plant material taken from growing crops. If the plants have been reared in peat pots, or can otherwise be planted out without disturbing the soil around their roots, the time of planting does not affect establishment.

Method of planting. — R. *arcticus* was planted on level ground in the experiments. Experience gradually showed that intervals of at least one metre should be left between the rows, but slightly larger intervals, e.g. 1.2 m, might be still more suitable. Passage-ways were arranged between the rows. Such ways could be covered with some material that cannot be penetrated by the plants, e.g. strong plastic sheeting, a sufficiently thick layer of bark or wood chips, or planks. Planks were used in some of the cultivation experiments.

When material was taken from a growing crop, it was planted out in a continuous, ca. 15-cm-deep furrow, which was dug by spade The roots and shoots were not separated into individual plants. Potted plants or plants with the soil still attached to their root systems can be planted out at a distance of 20—30 cm from each other, and with the same intervals between the rows as above. Watering is generally necessary.

The plants spread out sideways from the rows and after two or three years had filled the whole of the intervening space. They also tried to spread out over the borders of the experimental area. This was prevented by sinking vertical partitions of roofing felt or plastic sheeting in the ground.

As mentioned before, in the cultivation experiments R. *arcticus* was planted out on level ground. However, in its natural habitats the plant often grows on hummocks, with dependent shoots. An attempt was made to examine the advantages of this type of substrate. As separate hummocks are difficult to arrange, the plants in this cultivation experiment were grown in raised beds. The length of the beds was 2 m, the width of their base 0.8 m and their height 0.25 m. The sides of each bed were covered with one of three materials: transparent plastic sheeting, black plastic sheeting or planks. Beds bordered with the same material were arranged side by side in groups of three, and there were altogether six such groups. In three of the groups the beds extended from north to south, and in three from east to west. Plants of strain H/A were grown in the middle bed of each group and plants of strain P in both side beds. They were planted in one row along the open, ca. 20-cm-wide strip of soil on the top of the raised bed. The date of planting was 9. VII 1966. The surface of the soil was covered with fresh sphagnum moss.

The transparent plastic rotted and was removed the following year. The black plastic and the planks were removed in spring 1968. They prevented the plants from spreading, which they had a very strong tendency to do, as the top of the bed was already over-full. The sides of the bed were always covered with sphagnum moss immediately after the removal of the plastic or planks.

R. *arcticus* appeared to do well in these beds and the berry yields were fairly high. They were determined for two rows in each group, one of either strain (Table 13).

The north-south oriented beds, in which the solar radiation was more evenly distributed, clearly gave a better yield than those with an east-west orientation. R. *arcticus* thus did not appear to benefit by the slight shade on the north side of the latter beds. The smaller yields obtained from strain P may be due to the fact that it had another strain on only one side of it, whereas strain H/A had another strain on both sides. Otherwise

Table 13. Combined yields kg/are from raised beds in 1967—68.
Taulukko 13. Sadot mesimarjan penkkiviljelykokeesta yhteensä kg/a v. 1967—68.

Direction of beds *Penkkien suunta*	H/A kg/are	P kg/are	Mean *Keskim.* kg/are
N-S	61.2	57.7	59.4
E-W	51.9	35.3	43.6

strain P had generally given a better yield than strain H/A.

In 1968, R. *arcticus* was planted on ridges, with the aim of discovering whether the species has any preference for shade. The ridges were 80 cm high with an east-west orientation. R. *arcticus* was planted along the top, and the whole of the ridge was covered with a thick layer of fresh sphagnum moss.

The plants clearly spread more rapidly to the south side of the ridges than to the shady north side. R. *arcticus* appeared to do well on these ridges, but cultivation on level ground is preferable, since it facilitates the care of the plants.

423. Covering of soil surface

It proved necessary to cover the soil surface with some suitable material to keep the berries clean (Fig. 13 b, p. 25). Different materials were tried for this purpose, the following qualities being required: the material should (1) cover the soil surface completely, (2) be penetrable to the shoots, (3) not attract the root system to the cover, (4) remain unhumified for the life of the crop, 4—5 years, (5) be easily removed for possible further use, or have no deleterious effects when ploughed into the land.

Table 14. Mean temperatures in uncovered soil at depths of 10 and 30 cm, at 8 and 15—17 hours, and amounts by which means of soils below different covering materials deviated from these values. Measurements made daily in period 8. VI—31. VIII 1965.

Taulukko 14. Maan lämpötilan keskiarvojen poikkeamat mulloksen keskiarvoista eri katteiden alla 10 ja 30 cm :n syvyydessä mitattuna päivittäin klo 8 ja 15—17 ajalla 8. VI—31. VIII 1965.

Cover *Kate*	10 cm depth, *syvyys*, °C		30 cm depth, *syvyys*, °C	
hr *klo*	8	15—17	8	15—17
Uncovered .... *Mullos*	14.6	18.1	15.3	15.5
Sand .... *Hiekka*	+0.5	+0.2	+0.2	+0.1
Sphagnum moss .... *Rahkasammal*	−0.6	−2.6	−1.4	−1.6
Sawdust .... *Sahajauho*	−0.5	−2.8	−1.3	−1.5
Peat .... *Kasvuturve*	−0.9	−2.5	−1.4	−1.6
Significance of differences between covers .... *Katteiden erojen merkitsevyys*	*	**	**	**

The effect of covering the surface on the temperature of the underlying soil was examined in summer 1965. The temperature was measured daily at 8 and 15—17 hr during the period 8. VI—31. VIII, 10 and 30 cm below the cover. Plastic tubes with just sufficient space for the thermometer were sunk in the soil to these depths. The tubes were kept tightly closed during the intervals between the measurements. The average values for the whole period are shown in Table 14.

There were statistically significant differences between the treatments in the temperature of the soil at depths of 10 and 30 cm. A covering of sand raised the temperature slightly compared with uncovered soil, whereas all the other materials significantly decreased it.

The temperature at 10 cm in uncovered soil was noticeably higher in the afternoon than in the morning. The temperature rose less in the covered soils, so that they differed more widely from the uncovered soil later in the day.

At a depth of 30 cm the temperature of the soil was roughly the same in the morning and the afternoon.

The effect of the different covering materials on the temperature and moisture of the soil was examined in 1970. R. *arcticus* thrives in a damp substrate, though it avoids really wet soils. The better the cover prevents moisture evaporating from the soil, the more favourable it is to R. *arcticus*.

The materials used in the experiment were: wood chips, raw conifer bark (trees barked

Table 15. Mean values for temperature and percentage of available water in uncovered soil, at depths of 10 and 20 cm, at 8 and 20 hours, and amounts by which means for soils beneath different covering materials deviated from these values. Measurements made twice weakly in period 10. VII—1. IX 1970.

Taulukko 15. Maan lämpötilan (°C) ja käyttökelpoisen veden määrän (%) keskiarvojen poikkeamat mulloksen keskiarvoista eri katteiden alla 10 ja 20 cm :n syvyydessä mitattuna kaksi kertaa viikossa klo 8 ja 20 ajalla 10. VII—1. IX 1970.

Cover *Kate*	Temperature °C *Lämpötila*		Available water % *Käyttökelp. vettä*	
hr *klo*	8	20	8	20
	10 cm depth — *syvyys*			
Uncovered *Mullos*	14.5	18.4	59.9	61.9
Wood chips *Puuhake*	+0.3	−0.9	+3.2	+3.0
Tree bark *Puunkuori*	+0.9	−0.7	+5.9	+5.1
Gravel *Sora*	+1.4	+1.9	+2.2	+2.4
Leca gravel *Leca-sora*	+1.3	+0.3	+7.8	+7.5
Sphagnum moss *Rahkasammal*	+0.4	−1.5	+7.0	+5.8
Significance of differences between covers *Katteiden erojen merkitsevyys*	***	***	***	***
	20 cm depth — *syvyys*			
Uncovered	15.2	17.3	55.9	56.8
Wood chips	+0.1	−0.7	+ 6.6	+ 6.5
Tree bark	+0.5	−0.5	+10.2	+ 9.8
Gravel	+1.4	+1.8	+ 9.6	+10.1
Leca gravel	+1.0	+0.5	+10.5	+10.2
Sphagnum moss	±0.0	−1.2	+12.4	+11.8
Significance of differences between covers	***	***	***	***

by machine), coarse sifted gravel (grain size 2—6 mm), light building gravel (Leca II) and fresh sphagnum moss. The thickness of the covering layer was ca. 2 cm for all the materials except sphagnum moss, for which it was 4—5 cm. The surface of the control plots was uncovered. There were two replicates.

Soil temperature was measured with a so-called industrial thermometer, which was placed in holes made in the ground with an iron rod each time a measurement was taken. The measuring depths were 10 and 20 cm. The soil moisture was determined as the proportion of available water, by the method developed by Bouyoucos (1954). Plaster of Paris blocks were placed at depths of 10 and 20 cm below the different covers. Measurements were performed twice a week at 8 and 20 hr during the period 10. VII—1. IX, on altogether 16 measuring days (Table 15).

Statistically very significant differences were found between the treatments in respect of both temperature and moisture at both depths. The differences between the values measured in the morning and the evening were smaller at a depth of 20 cm than at 10 cm.

The covering of gravel increased soil temperature most. The Leca gravel also had a warming influence on the soil. In contrast, the wood chips, and, above all, the sphagnum moss lowered the temperature of the soil compared with that of the uncovered soil.

Leca gravel and sphagnum moss affected soil moisture most favourably, and the influence of tree bark was also fairly beneficial. Wood chips and gravel proved to be the poorest materials in this respect, but even with them the soil dried out more slowly than when it was uncovered. The percentages of available water recorded at 8 hr at both depths on the

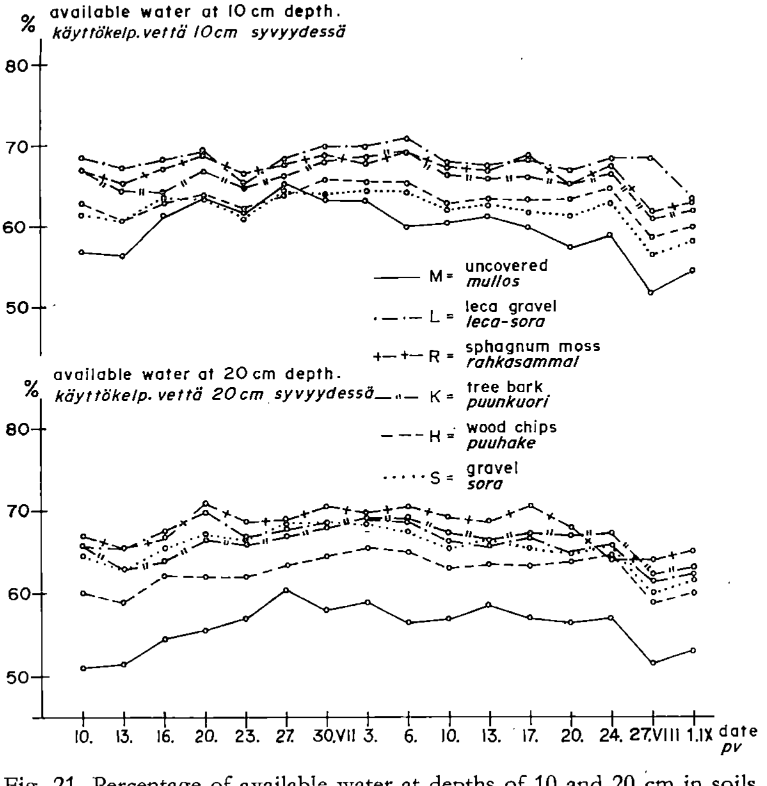


Fig. 21. Percentage of available water at depths of 10 and 20 cm in soils covered with different materials. Measurements made at 8 hours on various dates in the period 10. VII—1. IX 1970.

Kuva 21. Maassa olevan käyttökelpoisen veden määrä % eri katteiden alla 10 ja 20 cm:n syvyydessä klo 8 eri havaintopäivinä ajalla 10. VII—1. IX 1970.

Table 16. Mean values for temperature at 8 and 20 hours and percentage of available water at 8 hours, at depths of 10 and 20 cm in uncovered soil, and amounts by which means for soils beneath different covering materials deviated from these values. Measurements made once a week during the period 16. VI—1. IX 1971.

Taulukko 16. Maan lämpötilan (°C) ja käyttökelpoisen veden määrän (%) keskiarvojen poikkeamat mulloksen keskiarvoista eri katteiden alla 10 ja 20 cm:n syvyydessä mitattuna kerran viikossa, lämpötila klo 8 ja 20, käyttökelpoisen veden määrä klo 8, ajalla 16. VI—1. IX 1971.

	10 cm depth — *syvyys*			20 cm depth — *syvyys*		
	Temperature °C *Lämpötila* °C		Available water % *Käyttökelp. vettä %*	Temperature °C *Lämpötila* °C		Available water % *Käyttökelp. vettä %*
hr *klo*	8	20	8	8	20	8
Uncovered *Mullos*	13.5	17.7	49.6	13.6	17.1	52.8
Wood chips *Puuhake*	±0.0	−0.6	+5.1	±0.0	−0.9	+2.7
Tree bark *Puunkuori*	+0.1	−0.8	+8.2	+0.1	−0.8	+4.0
Gravel *Sora*	+0.6	+1.0	+3.8	+1.0	+0.8	+2.9
Leca gravel *Leca-sora*	+0.4	−0.3	+6.2	+0.8	−0.4	+1.6
Sphagnum moss *Rahkasammal*	−0.1	−1.3	+6.8	−0.2	−1.3	+3.7
Significance of differences between covers *Katteiden erojen merkitsevyys*	***	***	***	***	***	***

different observation days are shown in the diagrams in Fig. 21.

The experiment was performed again in 1971, measurements being made only once a week, on altogether 12 days. The results are shown in Table 16.

These results show the same trends as those of the previous year. Soil temperature was highest below a cover of gravel and lowest below sphagnum moss. All the covering materials clearly helped to keep the soil moist, tree bark and sphagnum moss being the most effective.

424. Weeds

The methods of weed control applicable in the cultivation of R. *arcticus* differ from those that can be employed in the care of other berry-bearing plants. For example, since R. *arcticus* spreads out over the field from its original rows, hoeing can be undertaken only while it is taking root just after being planted out.

Different measures can be taken against perennial weeds before R. *arcticus* is planted out. It was found that TCA employed against quick grass in the autumn did not have any deleterious effect on R. *arcticus* planted out in the following spring, even when applied at the rate of 100 kg/ha.

From 1965 onwards, weeds which spread by seed were controlled during the year of planting out by spraying the spaces between the rows with paraquat. Later fresh weed populations arose, when new wind-borne seeds arrived in the field (dandelion, fireweed, birch, willow, etc.). Preliminary experiments were therefore undertaken with different herbicides, the chief aim being to find a substance that would cause minimal damage to R. *arcticus*.

Experiment I. — The experiment was begun on 4. IX 1963 in plots in which different H strains had been planted out in 1960. Primatol S salt (4 % simazine) was applied at rates of 0, 0.5, 1, 2 and 3 kg/are. The results were examined in the following spring. The herbicide was found to have weakened the R. *arcticus* crops, particularly when used at the higher rates. The estimated cover percentages were as follows:

Treatment	Cover percentage
0	92
0.5 kg/are	88
1 »	55 Presumably not attributable to the salt alone
2 »	75
3 »	55

The deleterious effect on R. *arcticus* was rather noticeable. On the other hand, simazine does not destroy many of the most troublesome weeds, such as the dandelion, thistle, buckwheat and horsetail.

Experiment II. — The experiment was begun on 6. IX 1967 with the commercial preparations Gesagard 50 (active component prometryne), Afalon (linuron) and Teneran (chloroxuron). These were used at the following rates: Gesagard 50, 2 and 3 kg/ha; Afalon, 1.5 and 3 kg/ha; Teneran, 5 and 10 kg/ha. The R. *arcticus* crop was sprayed with a fine-nozzled sprinkling can. The temperature during spraying was +22.4 °C. The crop comprised strains H/A and P, and had been planted out in spring of the same year (1967).

The plants were examined on 4. X 1967 to ascertain whether they showed any signs of damage. The damage percentages for the different treatments were as follows:

	kg/ha	Damage %
Gesagard 50	2	25
	3	50
Afalon	1.5	60
	3	98
Teneran	5	+
	10	20

The damage done by Afalon was found to be particularly great. Little harm had been done by Teneran, but its effect on the weeds is slightly uncertain. The plants recovered so well that by the following year no clear difference could be noted between them. Young, vigorous plants can apparently withstand and recover from the damage caused by herbicides, even when it is quite pronounced.

Experiment III. — The experiment was begun on 6. VI 1968, and the same herbicides were used as in the preceding experiment, at the following rates: Gesagard 50, 2 kg/ha; Afalon 1 kg/ha; Teneran 3 kg/ha. R. *arcticus* had been planted out in 1964.

The damage percentages were 60, 70 and 10, respectively. Thus although the rates were comparatively low, the damage was much greater when the herbicides were applied early in the summer than when they were used in the autumn (experiment II). The young plants of early summer are thus more susceptible to damage than those of the autumn, which are already lignifying.

Experiment IV. — The experiment was begun on 12. V 1970. The herbicides and the rates of application were as follows: Primatol-Simazin (active component simazine 50 %) 2 and 4 kg/ha; Afalon 2 and 3.5 kg/ha; Gesagard 50, 2 and 3.5 kg/ha. The crop was of strain P and had been planted out in 1967. The herbicides were applied with a small spray. None of the leaves of R. *arcticus* had unfolded by that date.

The effects on the population were examined on 27. V 1970. Signs of damage were apparent only in the Gesagard plots. The margins of the leaves were partly faded, and the colour of the plants was somewhat lighter throughout the plots. Later in the summer these features had disappeared.

A new examination made on 9. VII 1970 showed that some weeds were present in all the plots.

E x p e r i m e n t V. — The experiment was begun in 1971 at the South Savo Experimental Station with R. *arcticus* that had been planted out in the preceding year. The following ten preparations were used: Betanal (active component phenmedipham, 5 kg/ha), Bladex (cyanazine, 4), Casoron G (dichlobenil, 50), Kerb RH 315 (propyzamide, 4), Orga 0345 (TFP, 4), Sinbar (terbacil, 1), Teneran (chloroxuron, 10) Tribunil (methabenzthiazuron, 3), Ustinex Z (diuron +methabenzthiazuron, 50) and Venzar (lenacil, 3 kg/ha). The preparations were applied on 26. V 1971.

These preparations can be divided into three groups on the basis of the effects produced by them that summer on R. *arcticus.*

1. The least deleterious preparations seemed to be Betanal, Kerb and Orga. When the two last-mentioned herbicides were used, some abnormal features could, however, be noted in the R. *arcticus* plants later in the summer. The leaves curled up (Kerb) or retained an indeterminate green colour (Orga), instead of turning red towards the end of the growing season, as is normal in R. *arcticus.* The weeds were not greatly affected by these three preparations.
2. Teneran, Venzar and Sinbar also caused fairly little damage to R. *arcticus* and had a much clearer effect on the weeds than the preceding preparations. They thus appear to be fairly promising, but further experiments are needed.
3. Bladex, Casoron, Tribunil and Ustinex had a markedly deleterious effect on R. *arcticus,* but gave good control of the weeds.

425. Plant diseases and insect pests

P l a n t d i s e a s e s. — Various rusts were observed in the cultivated crops of R. *arcticus,* and could even occur in quantity, especially towards the end of the summer and in the plants originating from artificial pollination. The rusts were identified at the University of Turku as *Phragmidium arcticum* Lagerheim and *Pucciniastrum arcticum* (Lagerh.) Tranzschel. The extent of the damage caused was difficult to assess. However, when occurring abundantly, they presumably interfered with the normal development and fruiting of the plants. Their occurrence varied from year to year, evidently depending partly on the weather conditions.

I n s e c t p e s t s. — Thrips were the commonest insect pests. These were identified at the Department of Pest Investigation at Tikkurila as *Thrips major* Uz., which was clearly the most abundant species on the samples examined, *Frankliniella intonsa* Tryb. and *Taeniothrips vulgatissimus* Hal. The thrips live in the flowers and imbibe fluids from the essential organs. They were observed to be more abundant in the natural stands than in the cultivated crops.

Blossom and raspberry beetles (*Meligethes* sp.) occurred together with the thrips. They damaged the stamens and carpels of the flowers.

The thrips and beetles were first noted in quantity on the cultivated plants in summer 1965. The weather was then generally cool and fairly rainy. However, the later half of July was dry, and the period between 18. VII and 26. VII was also warm, with some really hot days. It was then that the pests appeared. An attempt was made to examine their influence on the berry yield.

On 22. VII, 25 freshly opened flowers and 25 older flowers were marked in each of a number of plots with different strains of R. *arcticus,* with a view to studying their berry development. The procedure was repeated on 11. VIII, when, however, only 25 freshly opened flowers were marked per plot. The fruiting percentages were:

Strain	Fruiting % Marked on 22. VII Freshly opened	Older flowers	11. VIII Freshly opened
H/A	88	92	65
Le	78	96	69
Lu	76	84	67
P/h	91	100	92
P/N	88	100	92
P/S	92	96	84

The fruiting percentages were rather high, particularly among the older flowers. It thus appears that no great damage had been done, at least around the first marking time. The values for August were slightly lower. Fruiting was particularly good in strain P, 84—100 %.

In spite of these results, it seems probable that these insects may interfere considerably with fruiting if they occur in quantity.

Weevils, bugs, plant lice, etc. were also sometimes found on the plants, but so far have not been observed to be of much importance.

The control of these pests is complicated by the fact that the plants bear flowers and ripe berries at the same time. The only insecticides that can be used would be those whose toxic residues disappear within a few days, and that do not harm the pollinating insects.

Malathion, parathion and an aerosol containing pyrethrin ('Raid') were tried on the crops.

Malathion did not give complete control of the thrips. Rain falling shortly after the spraying may be partly responsible for the poor results. Parathion and pyrethrin proved to be efficacious. The toxic effect of malathion and parathion lasts for three weeks, so that their use must be restricted to the beginning of the summer. Pyrethrin evaporates rapidly.

426. Harvesting the berries

Since R. *arcticus* is a low-growing plant, the berries are close to the soil surface, and often concealed by the leaves, particularly in densely branched crops. Their size is also comparatively small for singly growing berries. The berry cannot be separated from the receptacle but the peduncle breaks easily at the base of the receptacle.

The time of fruiting is prolonged, two or even two-and-a-half months. The berries should be picked at least once a week, and even oftener at the height of the fruiting season. The harvesting is thus laborious.

The time required for harvesting was examined in summer 1970. The rate of harvesting varied considerably with the picker. It also depended on the abundance of ripe berries at the time of picking.

The average rate of harvesting was 809 g/hr, or 74.2 min/kg. The maximum rate of ca. 2 kg/hr was achieved at the height of the fruiting season, when ripe berries were particularly abundant.

427. The berry yields

a. Experiments with different strains

The plants were cultivated on level ground. Over the years the spaces between the plants and the rows were changed as new experiments were commenced. The spaces between the rows were increased in the years 1933—59 from the original 30 cm to 40—50—100 cm, and the distances between the plants were also varied, 20—40—50—20 cm (Table

Table 17. Data on the cultivation of R. *arcticus* in the years 1933—59: dates of planting out, intervals between rows and plants, and area of cultivated ground.

Taulukko 17. Mesimarjaviljelysten istutusajat, rivi- ja taimivälit sekä pinta-alat v. 1933—59.

Experiment *Koe*	Date of planting *Istutusaika*	Row interval *Riviväli* cm	Plant interval *Taimiväli* cm	Ground area *Pinta-ala* m^2
I	15. X 1933	30	20	28.6
II	24. V 1937	40	20	25.7
III	15. VIII 1938	40	40	91.5
IV	15. X 1940	40	40	28.2
V	31. V 1947	50	50	45.0
VI	18. IX 1950	100	20	120.0
VII	6. IX 1957	100	20	47.5

17). The subterranean partitions were not used in those years (experiments I—VII).

The soils in experiments I—VI were fine sand. Experiment VII was performed on peatland.

Fertilizers used:

Experiment I: spring 1935, 300 kg/ha Psf + 150 K_{40} + 150 Nks

Experiment II: autumn 1936, 40 tons fm, spring 1937, 300 Psf + 150 K_{40} + 150 Nks

Experiment V: spring 1950, 300 Nam

Psf = phosphate fertilizer, 20 % P_2O_5
K_{40} = potassium » 40 % K_2O
Nks = nitrogen » 15.5 % N
Nam = » » 20.5 % N
fm = farmyard manure

Table 18. Berry yields (kg/are) obtained from the original mixed population of R. *arcticus* and the different H strains in the years 1935—59.

Taulukko 18. Mesimarjasadot alkuperäisellä sekakasvustolla ja eri H-kannoilla kg/a v. 1935—59.

Experiment I, mixed population, yields for 1935—39: 17.7, 19.7, 41.8, 0.6, 1.1 kg/are
Koe sekakasvusto, sadot

Experiment II	1937	1938	Total *Yht.*	Relative value *Suhde-luku*
H/A	2.9	0.8	3.7	100
H/B	3.2	0.9	4.1	111
H/C	2.3	0.8	3.1	84
Experiment III	1939	1940		
H/A	12.4	29.5	41.9	100
H/B	8.0	12.0	20.0	48
H/C	12.7	25.2	37.9	90
Experiment IV	1942	1943		
H/A	15.8	3.7	19.5	100
H/B	13.7	1.0	14.7	75
H/C	9.3	0.2	9.5	49
H/D	8.0	0.2	8.2	42

Experiment V	1949	1950	1951	1952	Total *Yht.*	Relative value *Suhde-luku*
H/A	16.0	25.1	49.0	3.8	93.9	100
H/B	3.8	19.1	23.0	2.7	48.6	52
H/C	0.8	10.4	35.3	4.5	51.0	54
H/D	1.3	15.8	37.2	1.5	55.8	59
Experiment VI	1952	1953	1954	1955		
H/A	2.4	2.5	0.2	1.4	6.5	100
H/B	0.1	1.8	0.1	0.5	2.5	38
H/C	0.4	0.8	1.6	3.2	6.0	92
H/D	0.2	0.4	1.2	1.7	3.5	54

Experiment VII	1958	1959	Total *Yht.*	Relative value *Suhde-luku*
H/A	3.8	15.2	19.0	100
H/B	1.1	7.1	8.2	43
H/C	1.2	8.6	9.8	52
H/D	1.5	7.8	9.3	49
H/L	1.3	7.7	9.0	47

Fertilizer was not applied at any other time. The plant material was the original mixed population in experiment I and different H strains in experiments II—VII (Table 18).

Berry picking was begun on average in the middle of July and continued for the first half of August.

The average weight of the berry was about 750 mg. It varied so much from year to year in the same strain that no clear differences could be noted between strains. The weight of the berry rose above 1 g only in the years 1939, 1940 and 1942. In those years the berries of strain H/C were generally larger than those of the other strains.

The berry yield was often rather poor in the years 1935—59. The best yields were obtained from the original mixed population (experiment I, 41.8 kg/are in 1937) and in experiments III and V. The yields recorded for experiment III relate only to the two years following the year of planting out, but are rather promising. The highest yield in the years 1935—59 was 49 kg/are. It was obtained in 1951 from strain H/A in experiment V.

The yields reached their maximum in the fourth year after planting out (experiments I and V), when the plants were at their best. In the following year the yield generally dropped sharply.

When the age of the crops is taken into account, the poorest berry years appear to be 1938, 1943, 1952—55 and 1958. The good berry years were 1937, 1939, 1940, 1950 and 1951. The poor years were generally rainy or were characterized by particularly long, dry heat-waves (1955). In the good berry years precipitation was close to normal or slightly less than normal.

In these experiments strain H/A was clearly the most productive. It was inferior (to H/B) only in experiment II, but the level of the yields in this experiment was especially low and the differences between the yields are therefore not noteworthy.

Experiment VIII. — In spring 1960 material obtained from different parts of Finland was planted out in isolated plots. The area of the plots was 1.1 m $\times$ 2.2 m $=$ 2.42 m^2. The number of replicates was generally five, but in some of the strains there were only enough plants for two or three. The material was planted in four 0.5-m-long, transverse rows in each plot. The yields were recorded for the years 1961—63 (Table 19).

From the beginning, strain P clearly proved

Table 19. Berry yields obtained from various strains of *R. arcticus* in the years 1961—63.

Taulukko 19. Satotulokset eri mesimarjakannoilla v. 1961—63.

Strain *Kanta*	No. of replicates *Kerrant. luku*	Yield kg/are — *Sato kg/a* 1961	1962	1963	Total *Yht.*	Relative value *Suhde-luku*	Wt of berry *Marjan paino mg*
P	5	19.3	31.8	67.2	118.3	217	982
Hä	2	2.1	5.3	61.1	68.5	126	729
Le	3	2.4	0.9	60.6	63.9	117	938
H/A	5	5.0	5.4	44.1	54.5	100	747
H/D	5	3.3	2.0	43.0	48.3	89	950
T_3	2	1.1	4.0	28.5	33.6	61	685
T	2	0.3	0.1	21.7	22.1	41	740
Ap	5	0.5	0.4	19.7	20.6	38	605

Harvesting times: 1961 14. VII—18. IX
Korjuuajat: 1962 20. VII—3. IX
1963 29. VI—15. VIII

to be the best of the strains. Its total yield of 118 kg/are for the three years was more than 1.5 times as great as the second highest yield, produced by strain Hä, and more than twice as great as that of strain H/A. The highest yield of any of the replicates was 96 kg/are, and was obtained in 1963, when the plants were at their most productive age. The weight of the berry was also greatest in strain P.

Experiment IX. — A comparative experiment was commenced on 23. V 1960 with the different H strains. The size of the plots was 1.1 m × 3.3 = 3.63 m², and the replicates numbered four. As in the previous experiment, the material was planted out in 0.5-m-long, transverse rows, six rows in each plot. The area was covered with a layer of peaty soil. The yields for 1963 are shown in Table 20.

H/A and H/B gave rather high yields in this experiment, over 50 kg/are. Strain H/D had the largest berries.

Experiment X. — The experiment was begun in spring 1964 (planted out 30. V —3. VI). The size of the plots was 7 m × 8 m = 56 m². Strains H/A, Le and Lu each had one plot; strain P had two plots, designated P/N and P/S. Each plot had six 8-m-

Table 20. Berry yields obtained from the H strains in 1963.

Taulukko 20. Satotulokset eri H-kannoilla v. 1963.

Strain *Kanta*	kg/are *kg/a*	Relative value *Suhdeluku*	Wt of berry *Marjan paino* mg
H/A	53.7	100	780
H/B	50.8	95	812
H/C	32.1	60	892
H/D	38.8	72	964

Harvesting time: 3. VII—19. VIII
Korjuuaika:

Table 21. Data on berry yields obtained from various strains of R. *arcticus* in 1965—67.

Taulukko 21. Satotulokset eräillä mesimarjakannoilla v. 1965—67.

Strain	1965			1966		1967		1965—67	
	Yield kg/are	Wt of berry mg	Colour 0—100	Yield kg/are	Wt of berry mg	Yield kg/are	Small berries % wt of yield	Total — *Yht.* kg/are	Rel. value
Kanta	*Sato kg/a*	*Marjan paino mg*	*Väri* 0—100	*Sato kg/a*	*Marjan paino mg*	*Sato kg/a*	*Pieniä marj.p-%*	*kg/a*	*Suhdeluku*
P/S	12.6	1321	94	44.5	892	27.1	15.9	84.2	229
P/N	16.7	1227	95	27.5	818	24.6	22.1	68.9	187
Lu	11.4	995	66	24.2	578	28.0	14.8	63.6	173
Le	10.2	1166	61	22.5	881	25.2	10.4	57.9	157
H/A	6.6	1301	97	19.4	733	10.8	36.7	36.8	100

Colour 0—100: 0 = no red colour in berries
Väri: *marjoissa ei lainkaan punaista väriä*
100 = berries with strong uniform red colour
marjat tasaisen voimakkaan punaisia

Table 22. Data on berry yields obtained from some strains from southwest Finland in 1965—67.

Taulukko 22. Satotulokset eräillä Lounais-Suomesta peräisin olevilla kannoilla v. 1965—67.

Strain *Kanta*	1965 Yield kg/are *Sato kg/a*	1965 Wt of berry mg *Marjan paino mg*	1965 Colour 0—100 *Väri 0—100*	1966 Yield kg/are *Sato kg/a*	1966 Colour 0—100 *Väri 0—100*	1967 Yield kg/are *Sato kg/a*	1967 Wt of berry mg *Marjan paino mg*	1965—67 Total kg/are *Yht. kg/a*	1965—67 Rel. value *Suhdeluku*
P	30.9	1229	91	51.0	71	24.1	961	106.0	204
H/A	12.8	1232	60	27.4	53	11.7	871	51.9	100
Ma	9.2	777	40—85	20.4	45—90	10.5	639	40.1	77
Pa	8.7	952	36	14.5	48	8.8	814	32.0	62
My	5.6	896	33	15.4	41	9.8	701	30.8	59

Harvesting times: 1965 20. VII—6. IX
Korjuuajat 1966 8. VII—7. IX
1967 25. VII—25. VIII

H/A = control strain

long rows, and was covered with a layer of fresh sphagnum moss about 5-cm-thick. The yields were recorded for the years 1965—67 (Table 21).

As in experiment VIII, strain P proved to be the most productive. Plot P/S gave a particularly good yield. The three-year yield of strain Lu was about 20 kg/are lower than that of strain P/S. The yield of H/A was a little less than 50 % of that of plot P/S. In 1967, H/A also clearly had the largest number of small berries (drupelets < 10).

E x p e r i m e n t XI. — The experiment was begun in June 1964. The plants originated from Marttila (Ma), Mynämäki (My) and Paimio (Pa). Material of strains H/A (control) and P was also included. The sizes of the replicate plots for the different strains were 2, 2 and 4 m^2, so that each strain had an area of 8 m^2. The experimental area was covered with peat. Details of the yields for the years 1965—67 are given in Table 22.

The yield of strain P was about twice as large as that of strain H/A. Strains Ma, My and Pa were all clearly less productive than strain H/A, and their berries were generally light-coloured. Some of the berries of strain Ma were light and some were very dark. The three new strains did not represent pure clones, the material being obtained from small scattered occurrences in each of the three localities.

b. Fertilizer experiments

E x p e r i m e n t I. — The first fertilizer experiment was begun in 1964 with the different H strains, which had been planted out in 1960. The size of the plots was 3.63 m^2. Chlorine-free compound fertilizer Y (5 % N—12 P_2O_5—15 K_2O) was applied at rates of 0, 5, 10 and 15 kg/are, on 30. V 1964 (Table 23).

The yields were greater at rates of 5 and 10 kg/are than at 15 kg/are. The weight of the berry showed no regular trend.

E x p e r i m e n t II. — The experiment was begun in 1966. Material of strain P had been planted out in a sand-covered experimental area in 1964. The size of the plots was 4 m^2, and the replicates numbered two. The fertilizers were mixed with water and applied on 23. V. The 0 plots received pure water. The experiment was continued in 1968 with some changes in the fertilizers. They were applied on 30. V without water, the borate

Table 23. Influence of fertilizer (chlorine-free compound Y) on yield and size of berry in the H strains in 1964.

Taulukko 23. Lannoituksen (kloorivapaa Y-lannos) vaikutus satoon ja marjan painoon eri H-kannoilla v. 1964.

Strain *Kanta*	Fertilizer kg/are *Lannoitus kg/a*	Yield kg/are *Sato kg/a*	Relative value of yield *Sadon suhdeluku*	Wt of berry mg *Marjan paino mg*
H/A	0	17.9	100	617
	5	21.5	120	580
	10	22.1	123	709
	15	19.2	107	625
H/B	0	25.2	100	720
	5	22.3	88	597
	10	26.0	103	640
	15	23.2	92	664
H/C	0	16.4	100	752
	15	17.2	105	771
H/D	0	17.5	100	554
	5	31.3	179	727

Table 24. Results obtained in fertilizer experiment with strain P in 1966 and 1968.

Taulukko 24. Lannoituskokeen tulokset P-kannalla vuosina 1966 ja 1968.

Treatment and fertilizer kg/are *Koejäsen ja lannoitus kg/a* 1966	 1968	1966 Yield kg/are *Sato kg/a*	 Rel. value *Suhde-luku*	 Wt of berry mg *Marjan paino mg*	1968 Yield kg/are *Sato kg/a*	 Rel. value *Suhde-luku*	 Wt of berry mg *Marjan paino mg*	 Small berries % wt of yield *Pieniä marjoja p-%*
a = 0	0	41.0	100	839	9.0	100	828	37.7
b = 0.2 Bl	0.1 Bl	47.7	116	836	10.6	118	900	42.5
c = 3 Nks	3 Nks	41.2	100	779	8.1	90	839	38.5
d = 3 Ksu	0	33.1	81	748	7.7	86	775	35.4
e = b+c+d	b+c	46.6	114	787	7.9	88	824	41.3

Bl = borate fertilizer — *lannoiteboraatti* (B 14 %)
Nks = calcium saltpetre — *kalkkisalpietari* (N 15.5 %)
Ksu = potassium sulphate — *kaliumsulfaatti* (K_2O 50 %)

fertilizer being mixed with sand (Table 24).

Apart from treatment e in 1968, only the plots receiving boron had increased yields. In 1968 all the yields were poor and there was a large proportion of small berries.

It has been observed that when the yield drops in older crops, the proportion of small berries generally increases considerably. The present crop was presumably already past its prime.

Soil samples were taken from the plots on 9. IX 1966. Analyses showed that the soil of the experimental area, which was very fine sand, was fairly homogeneous as regards the essential elements. The range of variation of the values of four samples taken from the 0 plots was as follows: pH 5.6 in all, Ca 1250—1325, K 88—96, P 7.5—9.2, Mg 90—130 mg/l and electrolytic conductivity 0.5—0.6.

As the yields obtained from the two replicates of treatment b differed greatly from each other (b_1 = 26.7 kg/are, b_2 = 68.7 kg/are), the soil of the two plots was analysed for both the essential and the trace elements. The results were as below. Fe is given as a percentage and the other elements as mg/l:

	pH	Ca	K	P	Mg	Fe	Co	B	Cu	Mn	Zn	Mo	Conductivity
b_1	5.6	1300	90	8.0	95	0.8	5.5	0.6	5.2	5.5	38	0.9	0.5
b_2	5.6	1250	88	9.2	130	0.8	6.0	0.2	6.2	5.5	46	1.2	0.6

Differences were apparent in the nutrient contents. Plot b_2, which gave the better yield, had slightly less Ca and K and noticeably less B than b_1. On the other hand, it had more P, Mg, Co, Cu, Zn and Mo. Thus, on the whole, b_2 was richer in nutrients than b_1. The significance of boron for fruiting remained uncertain. The boron content of the plot with the higher yield was particularly low.

Experiment III. — The experiment was begun in 1968. Strain Le had been planted out in the experimental area in 1964. The population was already clearly past its prime, and an attempt was made to stimulate it with fertilizer.

The area of the experimental plots was 14 m². The fertilizers were applied on 6. VI at the following rates: 0, 5 kg/are norm. compound fertilizer (Yn; 8—13—9), 0.2 kg/are fertilizer borate (Bl; B 14 %), and 6 kg/are magnesium sulphate ($MgSO_4$; Mg 19 %). Only one fertilizer was applied to each plot. The results are shown in Table 25. Boron and magnesium produced a slight increase in the yields, but the primary essential elements contained by Yn had no effect. As in experiment II, a rather large proportion of the yields consisted of small berries. No rejuvenating effect on the crop could be observed. The productivity of an aged crop can apparently not be prolonged with the aid of fertilizers. The absence of replicates decreases the reliability of these results.

Experiment IV. — In 1970 an experiment was arranged in an area in which strains H/A and P had been planted out in alternate rows in 1967. Garden Super Y fertilizer (11—11—22) was applied at rates of 0, 4 and 8 kg/are. This fertilizer contains both essential elements and many trace elements, such as B, Cu and Mn. It was applied on 19. V. The size of the plots was 5 m², the replicates

Table 25. Fertilizer experiment with aged crop of strain Le in 1968.

Taulukko 25. Lannoituskoe yli-ikäisessä Le-kantaa olevassa kasvustossa v. 1968.

Treatment *Koejäsen*	Yield kg/are *Sato kg/a*	Relative value *Suhdeluku*	Wt of berry mg *Marjan paino mg*	Small berries % wt of yield *Pieniä marjoja p-% sadosta*
a = 0	4.8	100	715	37.6
b = Yn	3.6	75	771	28.5
c = Bl	10.9	227	825	24.9
d = $MgSO_4$	8.8	183	796	31.9

Table 26. Results of application of Garden Super Y fertilizer to strains H/A and P in 1970.

Taulukko 26. Puutarhan super-Y-lannoksen käyttökoe H/A- ja P-kannalla v. 1970.

Strain *Kanta*	Rate kg/are *Lannoitus kg/a*	Yield kg/are *Sato kg/a*	Yield Relative value *Sato Suhdeluku*	Wt of berry mg *Marjan paino mg*	Wt of berry Relative value *Marjan paino Suhdeluku*	Small berries % wt of yield *Pieniä marjoja p-% sadosta*
H/A	0	30.6	100	970	100	6.5
	4	43.5	142	1248	129	6.3
	8	44.2	144	1405	145	7.8
P	0	33.0	100	1153	100	3.5
	4	51.7	157	1205	105	4.5
	8	56.9	172	1418	123	5.4
H/A + P	0	31.8	100			
	4	47.6	150			
	8	50.5	159			

numbered four in treatment 0, and two in each of the other treatments.

The application of fertilizer very clearly increased both the yields and the size of the berries (Table 26). It also clearly benefited the plants. Those in the plots receiving fertilizer were much greener than the plants in the 0 plots, which were already beginning to turn reddish by the middle of the summer. The crop was at its best age and had spread over the entire area. As the plants had received no earlier applications of fertilizer, there may already have been a scarcity of nutrients.

On 19. VIII soil samples were taken for analysis from the plots not receiving fertilizer. The results were as follows: soil type very fine sand, pH 6.1, Ca 1450—1575, K 174—192, P 18—23, Mg 130—165, B 0.4—0.5, Cu 5.8—7.2 and Mn 1.5—2.0 mg/l. The electrolytic conductivity was 0.4—0.5.

E x p e r i m e n t V. — In 1970 the preceding experiment was repeated with a crop which was one year younger, having been planted out in 1968. The strains were Le, Lu and P planted out in alternate rows. The size of the plots was 5 m^2, and there were no replicates, except for the 0 treatment, which had two.

As in experiment IV, the application of fertilizer clearly increased both the yield and the size of the berries (Table 27).

The strains reacted to the fertilizers in slightly different ways. The yield of strain Le was noticeably smaller than the others in the 0 treatment, and increased by 66 % when fertilizer was applied at the rate of 4 kg/are. Strain P achieved an equally great increase only when the fertilizer was applied at the higher rate. Strain Lu had the highest yield level in this experiment.

In addition to the effect of the fertilizer on the yield and the size of the berry, attention was also paid in summer 1970 to its influence on the number and weight of the seeds, the size of the drupelets and the proportion of the weight of the berry relating to the seeds and the calyx. The berries examined were obtained from strains H/A, Le, Lu and P in fertilizer experiments IV and V. Strain H/A had been planted out in 1967, the others in 1968. A hundred berries were examined in strain Le and two hundred in each of the other strains (Table 28).

The fertilizer increased the size of the berry in all the cases. The number of seeds in the berry also rose in all but strain P. The weight

Table 27. Results of application of Garden Super Y fertilizer to strains Le, Lu and P in 1970.

Taulukko 27. Puutarhan super-Y-lannoksen käyttökoe Le-, Lu- ja P-kannalla v. 1970.

Strain *Kanta*	Rate kg/are *Lannoitus kg/a*	Yield kg/are *Sato kg/a*	Yield Relative value *Suhdeluku*	Wt of berry mg *Marjan paino mg*	Wt of berry Relative value *Suhdeluku*	Small berries % wt of yield *Pieniä marjoja p-% sadosta*
Le	0	14.6	100	611	100	5.9
	4	24.2	166	704	115	18.4
Lu	0	36.9	100	946	100	3.1
	8	44.4	120	1191	126	3.7
P	0	21.6	100	1069	100	5.5
	4	26.9	125	1094	102	4.5
	8	36.7	170	1376	129	2.8
Le + P	0	18.1	100			
	4	25.6	141			
Lu + P	0	29.3	100			
	8	40.6	139			

Table 28. Results of application of Garden Super Y fertilizer to various strains in 1970: effect on weight of berry, number and weight of seeds per berry, weight of seed and drupelet, and proportion of weight of berry relating to seeds and calyx.

Taulukko 28. Puutarhan super-Y-lannoksen vaikutus marjan painoon, siementen lukumäärään ja painoon marjassa, siemenen ja lohkon painoon sekä siementen ja verhiön osuuteen marjan painosta eräillä kannoilla v. 1970.

Strain *Kanta*	Rate kg/are *Lann. kg/a*	Wt of berry mg *Marjan paino mg*	Seeds/berry *Siem./marja kpl*	Wt of seed mg *Siem. paino mg*	Wt of drupelet mg *Lohkon paino mg*	% wt of berry (*Marjassa p-%*): Seeds *Siem.*	Calyx *Verh.*	Together *Yht.*	Relat. value *Suhdeluku*
H/A	0	850	26.2	1.78	32.4	5.50	3.22	8.72	100
	4	1250	35.7	1.81	35.0	5.21	2.83	8.04	92
	8	1410	37.1	1.93	37.9	5.07	2.86	7.93	91
Le	0	610	17.6	2.05	34.7	5.91	5.09	11.00	100
	4	700	20.7	1.84	34.0	5.41	4.20	9.61	87
Lu	0	1010	34.3	1.77	29.5	5.88	4.10	9.98	100
	8	1250	35.3	2.10	35.4	5.93	3.53	9.46	95
P	0	1120	37.4	1.55	29.8	5.19	2.91	8.10	100
	4	1130	35.7	1.61	31.7	5.07	4.15	9.22	114
	8	1230	35.9	1.77	34.3	5.16	3.82	8.98	111

of the seed rose in all the strains except Le. The weight of the individual drupelets was also generally increased by the application of fertilizer.

The relative weight of the seeds and calyx decreased fairly clearly when fertilizer was applied. The only exception was strain P, in which the fertilizer increased the value by 11—14 %.

The effect of fertilizer on the quality of the berries is treated later on.

Fertilizer was applied in nature to a stand of R. *arcticus* at Lumijoki. A cleared area of about 4 ha had been ploughed years before and then left; R. *arcticus* had spread throughout the area and given good berry yields for many years. On 2. IV 1964, chlorine-free compound fertilizer Y was applied in the area at rates of 0, 5 and 10 kg/are. Later, towards the end of the summer, it was observed that the fertilizer had particularly benefited the grasses and other plants that had already spread to the area. The greater the application of fertilizer, the more R. *arcticus* was choked by these plants. Thus the application of fertilizer can only benefit R. *arcticus* when it is free from other vegetation. No berry yield was obtained that summer, either from the whole area, or from the part receiving fertilizer.

428. The renewal of crops and the choice of cultivation site

The renewal of crops. — The crops seemed to deteriorate rapidly once they had covered the whole area. This took 4—5 years, including the year of planting out.

The tendency of the plant to spread had been found to be rather strong, and it was decided to ascertain whether this could be put to use in the renewal of the crops.

An experiment was begun in spring 1970, in a young, vigorous crop (strains H/A and P planted out in 1967), which had covered the whole area. At 2-m intervals, 2-m-wide strips were cleared completely of the plants and their roots, the earth being turned up with a pitchfork. Fertilizer was applied to the cleared strips and they were covered with different materials (comparative experiment with covering materials, p. 45).

R. *arcticus* spread very slowly to these strips, although the neighbouring plots were almost overfull. By 1971 scarcely any spreading had occurred.

A similar attempt was made earlier (1969) on a smaller scale, 1-m-strips being cleared in a crop of strain Lu. The strips were cleared with several runs of a rotary hoe, but the remains of the old R. *arcticus* plants were not removed. This crop was older than the former one, having been planted in 1964, but still looked very vigorous. Plants of strain Lu have been found to have a somewhat longer life than, for example, plants of strain P, whereas those of strain Le have proved to be particularly short-lived.

In this case, too, the cleared strips were only very slowly colonized by R. *arcticus*. Apparently it avoids areas in which it has just been growing.

The best way of renewing R. *arcticus* crops was found to be by planting.

The choice of cultivation site. — The present investigations were performed at the North Savo Agricultural Experiment Station, which is situated in the optimal area of R. *arcticus*. The conditions prevailing during the experiments may be considered to be favourable to R. *arcticus* for the following reasons: (1) the proximity of the lake increases the atmospheric humidity and decreases the risk of frosts occurring during the growing season, (2) precipitation is comparatively uniform throughout the summer, as is usual in the lake district in the interior of Finland, (3) the snow-lie in winter is thick and long, so that R. *arcticus* does not commence growth too early in the spring, (4) colonies of bees in the vicinity ensured a good supply of pollinating agents.

Some simple watering experiments were arranged during the course of the present research, but did not give particularly good results. Watering was perhaps started too late, being begun only after a comparatively long period of dry weather. Favourable moisture conditions can be achieved fairly easily in the substrate by means of watering, but the atmospheric humidity is presumably of equal importance. The latter can most suitably be regulated by choosing a cultivation site near water, or at least in an area which is sheltered from the wind. The fluctuations in temperature are also smaller in such sites than in more exposed places. Areas where frosts often occur in the spring are not suitable for R. *arcticus*.

The microclimate is thus of considerable importance for the successful cultivation of R. *arcticus*. Possible limitations in the information which can be obtained from experiments performed under the same conditions and in the same cultivation site will no doubt soon be compensated by the pilot cultivations begun in different parts of Finland in the last few years. The practical cultivation of R. *arcticus* just begun in summer 1972 may also be expected to provide information on the prerequisites of the success of this plant. The results of the pilot cultivations have already suggested that success is more certain when R. *arcticus* is cultivated within its optimal area, between 62° and 66° N latitude, but the microclimate is of great importance in all regions.

43. The quality of the berries of R. *arcticus*

A preliminary investigation of the quality of the berries was made in summer 1970. The berries of various strains were examined, attention being paid to the influence on their quality of the stage of maturity, the application of fertilizer and the period of storage. The criteria used in assessing the quality were aroma, taste, appearance and colour.

The quality of the berries was first examined on fresh samples by means of sensory tests. In addition, the soluble dry matter and acid content were determined on frozen samples. The chemical analyses were performed at the Laboratory for Food Research and Technology, the State Institute for Technical Research, at Otaniemi. The other tests were made at the North Savo Experimental Station.

431. Material and methods

The strains used in the investigations were H/A, Lu and P. Strain P was represented by two samples, P_1 and P_2. The samples of P_1 and H/A were taken from a crop planted out in 1967; the samples of P_2 and Lu were from a crop planted out in 1968. Strain Le had been planted out with the latter strains, but its berries were used only in the storage experiment. Fertilizer experiments had been arranged with these strains in spring 1970. Garden Super Y fertilizer was applied at rates of 0, 4 and 8 kg/are (fertilizer experiments IV and V, pp. 56—58). Both half-ripe and ripe berries were picked.

In the storage experiment the berries were stored both in a refrigerator, where the temperature ranged from +4 to +8 °C, and in a cellar, where the temperature was ca. 15—16 °C. The relative humidity was 40—90 % and 72—86 %, respectively. The storage periods were one and three days.

Soluble dry matter was determined with a refractometer on stained unfiltered solution (Official methods . . . 1965: 309). The soluble dry matter of the berries consists mainly of soluble carbohydrates or sugars (Joslyn 1970).

The acid content was determined as titratable total acid (Official methods . . . 1965: 316). The results are expressed as the consumption of bases ml 0.1-N NaOH/100 g berries. The acid of the berries of R. *arcticus* is mainly citric acid (Černova 1959, Levin 1961).

The aroma was judged organoleptically with the aid of dilution tests and dilution profilograms (Tilgner 1962, 1965).

The sugar-to-acid ratio was used in addition to the sensory tests in the assessment of the taste of the berries.

In the sensory tests the following points were awarded: aroma 0—4, taste 0—10, and appearance and colour 0—2. The panel of testers comprised 7—10 persons. The means of the results were calculated. The points awarded varied greatly with the tester within the agreed scales.

432. Results

a. Chemical analyses

The content of soluble dry matter seemed to depend on several factors, including the strain and the fertilizer used.

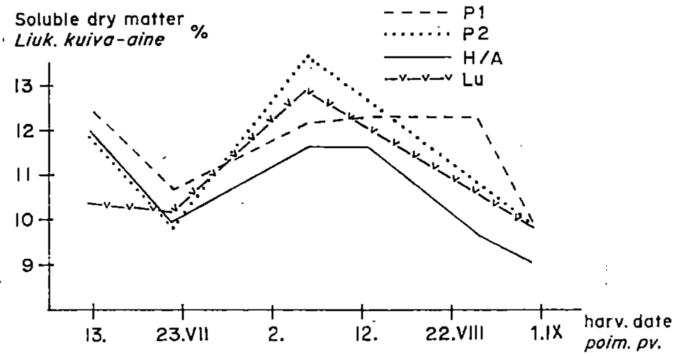


Fig. 22. Percentage of soluble dry matter in berries of various strains on different harvesting dates.
Kuva 22. Marjojen liukoinen kuiva-aine % kunakin poimintapäivänä eri mesimarjakannoilla.

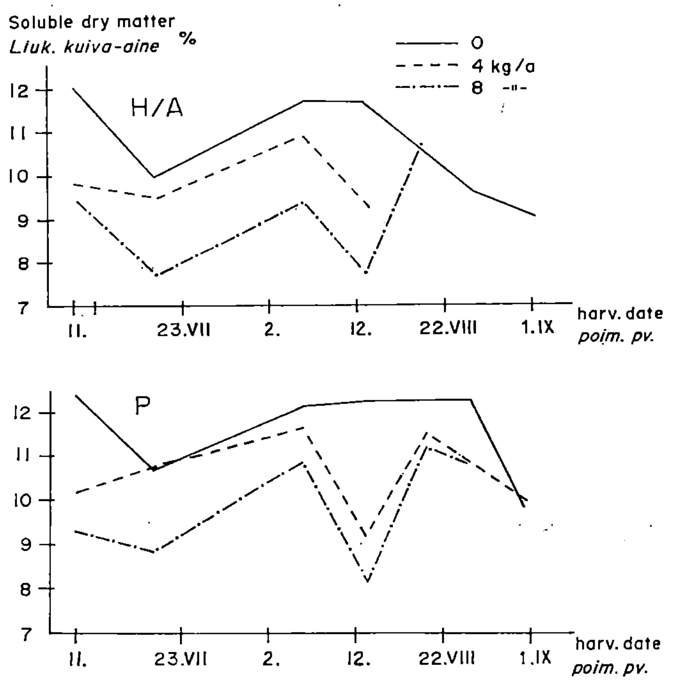


Fig. 23. Percentage of soluble dry matter in berries of strains H/A and P in fertilizer experiment.
Kuva 23. Marjojen liukoinen kuiva-aine % H/A- ja P-kannalla lannoituskokeessa.

The mean percentages for soluble dry matter in the different strains during the period 13. VII—6. VIII were:

H/A	11.2 %
Lu	11.0 %
P_1	11.7 %
P_2	11.8 %

The diagrams in Figs. 22 and 23 show the results obtained for different picking dates. The values are the means of five samples, the limits of variation being ±0.2. The determinations were made on diluted samples (1 : 1).

The soluble dry matter percentages differed between the strains. The values for strain P were slightly higher than those for Lu. The values for H/A were clearly lower than those of the other strains, except at the beginning of the picking season.

The application of fertilizer clearly decreased the soluble dry matter content. The relative decrease was greater when it was applied at

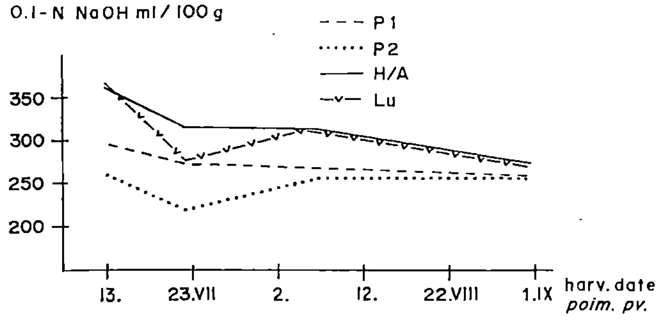


Fig. 24. Acid content of berries of various R. *arcticus* strains on different harvesting dates.
Kuva 24. Marjojen happoisuus kunakin poimintapäivänä eri mesimarjakannoilla.

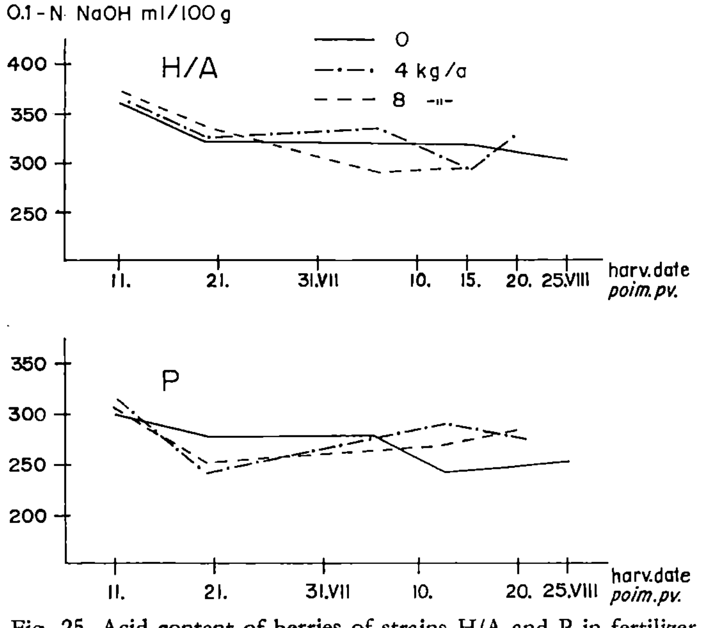


Fig. 25. Acid content of berries of strains H/A and P in fertilizer experiment.
Kuva 25. Marjojen happoisuus H/A- ja P-kannalla lannoituskokeessa.

the rate of 8 kg/are than at the rate of 4 kg/are. The results for strain H/A are incomplete at the end of the observation period owing to the scarcity of the berries.

The acid content of the berries also differed between the strains. The means of four samples for the period 11. VII—13. VIII 1970, expressed as consumption of bases, 0.1-N NaOH/100 g, were:

H/A	328 ml
Lu	309 ml
P_1	273 ml
P_2	254 ml

The diagrams in Figs. 24 and 25 show the acid content of the berries on different picking dates. The results are the means of two samples, the limits of the variation being ±0.3.

According to the results, the berries of strain P (Fig. 24) had the smallest acid content. The values of strains H/A and Lu were close to each other and clearly higher than those of strain P.

The curves in the diagrams in Fig. 25 run close to each other. The application of fertilizer does not appear to have an important influence on the acid content of the berries.

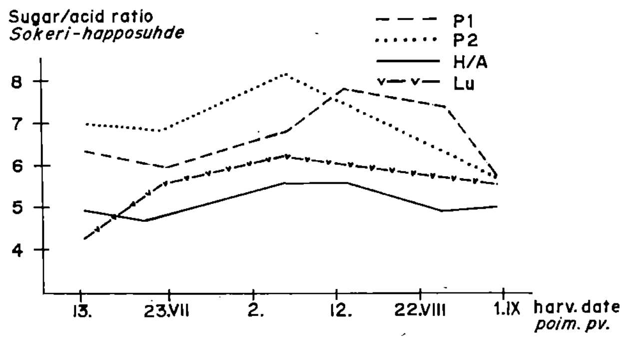


Fig. 26. Sugar-to-acid ratio of berries of various R. *arcticus* strains.
Kuva 26. Marjojen sokeri-happosuhde eri mesimarjakannoilla.

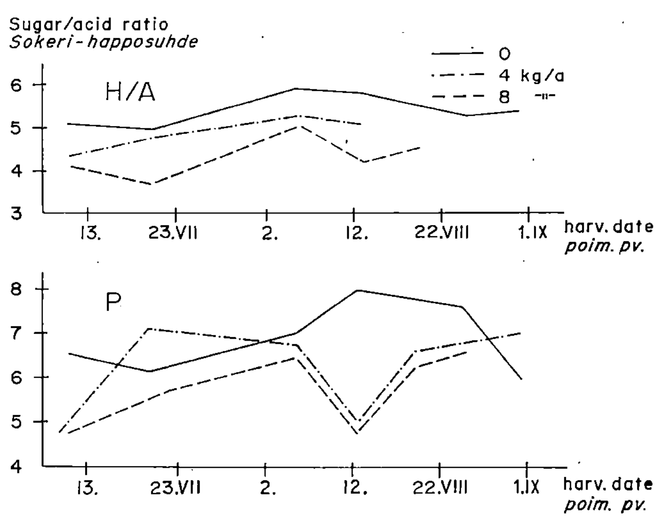


Fig. 27. Sugar-to-acid ratio in berries of strains H/A and P in fertilizer treatments.
Kuva 27. Marjojen sokeri-happosuhde H/A- ja P-kannalla lannoituskokeessa.

In the calculation of the sugar-to-acid ratio, used as an index of the taste, the value taken for sugar was its percentage of the soluble dry matter. The value for acid was calculated as the citric acid weight percentage. The sugar-to-acid ratios of the berries of the various strains are shown in Fig. 26, and the influence of the application of fertilizer on the berries of strains H/A and P is shown in Fig. 27.

The ratio was highest for the berries of strain P. The values for H/A and Lu did not differ so greatly from each other as from those for P. The sequence of the strains is the same when they are arranged in order of descending sugar-to-acid ratio as when they are arranged in order of descending soluble dry matter content.

The sugar-to-acid ratio generally decreased with increasing rates of fertilizer application, mainly owing to a decrease in the sugar content. The decrease in the ratio of strain P was not completely rectilinear. The best berries were obtained around the middle of August. The values for the plots not receiving fertilizer reached their maximum slightly later than those of the plots to which fertilizer was applied.

b. The sensory tests

The degree of maturity was of great importance for the aroma and taste. The aroma was strongest in the fully ripened berries. It was not fully developed in the half-ripe ber-

Table 29. Effect of storage on quality of berries as revealed by points awarded in sensory tests in 1970 for freshly picked and stored berries. Storage temperatures +5 and +15 °C; storage periods 1 and 3 days. Material: ripe berries of strains Le and P, and half-ripe berries of P (marked P/pk).

Taulukko 29. Marjojen laadun muuttuminen säilytyksen aikana aistinvaraisesti arvosteltuna v. 1970. Säilytyslämpötilat +5 ja +15 °C sekä säilytysajat 1 ja 3 vrk, kontrollina juuri poimitut näytteet. Materiaali: Le ja P kypsinä sekä P lisäksi puolikypsänä (merk. P/pk) poimittuina.

Strain *Kanta*	Freshly picked *Juuri poim.*	+5 °C 1 day *vrk*	 3 days *vrk*	+15 °C 1 day *vrk*	 3 days *vrk*
		Aroma 0—4 *Aromi*			
Le	3.1	2.9	2.2	2.8	2.1
P	3.1	3.0	2.8	3.0	2.1
P/pk	1.4	1.7	—	2.1	2.8
		Taste 0—10 *Maku*			
Le	7.8	7.0	6.6	7.4	5.7
P	8.1	7.6	7.3	6.7	5.4
P/pk	5.2	5.8	—	5.6	6.3
		Appearance and colour 0—2 *Ulkonäkö ja väri*			
Le	1.1	1.2	1.2	1.2	0.9
P	1.7	1.8	1.8	1.9	1.6
P/pk	1.0	1.1	—	0.9	1.1

ries and weakened again when the berries became over-mature. The taste dilution profilogram showed that the grass-like fragrance discernible in the half-ripe berries predominated over the true nectarberry aroma. After three days' storage at +15 °C, the nectarberry aroma predominated over the grass-like scent. When the berries were stored at +5 °C for three days, the aroma remained almost the same.

The aroma of ripe berries decreased when they were stored. (Table 29). Three days' storage at +15 °C produced a clear smell of fermentation.

Storage was found to improve the taste of half-ripe berries and to spoil that of ripe ones. High temperatures accelerated changes in the taste (Table 29).

The application of fertilizer had a somewhat unfavourable effect on the taste of the berries, this being more noticeable in strain P than in H/A (Table 30).

When arranged in descending order of excellence with respect to aroma and taste, the strains showed the following sequence: P, Lu (almost as good as P) and H/A. In the organoleptic tests P was judged to be clearly superior in respect to appearance and colour, and Lu and H/A were considered to be with each other roughly the same (Table 31).

Table 30. Effect of fertilizer on quality of berries of strains H/A and P as revealed by points awarded in sensory tests in 1970. Garden Super Y fertilizer applied at rates of 4 and 8 kg/are.

Taulukko 30. Lannoituksen vaikutus marjojen laatuun H/A- ja P-kannalla aistinvaraisesti arvosteltuna. Käytetty lannoitus 4 ja 8 kg/a puutarhan super-Y-lannosta.

Date of test *Hav. pv*	H/A 0	H/A 4 kg/are	H/A 8 kg/are	P 0	P 4 kg/are	P 8 kg/are
			Aroma 0—4 *Aromi*			
11. VII	2.7	—	2.1	3.5	—	2.5
20. VII	1.3	2.4	2.0	3.0	2.6	2.2
7. VIII	2.4	2.3	2.7	2.3	2.5	3.0
25. VIII	2.1	2.3	1.6	3.1	2.6	2.7
			Taste 0—10 *Maku*			
11. VII	6.7	—	6.0	7.9	—	6.4
20. VII	6.9	7.0	5.6	7.3	7.3	5.6
7. VIII	6.9	6.9	6.8	6.7	6.7	8.1
25. VIII	6.9	7.7	6.4	8.5	7.0	6.2
			Appearance and colour 0—2 *Ulkonäkö ja väri*			
11. VII	1.5	—	1.2	1.9	—	1.4
20. VII	1.2	1.4	1.5	1.5	1.4	1.3
7. VIII	1.3	1.6	1.7	1.4	1.7	1.7
25. VIII	1.6	1.6	1.4	1.9	1.3	1.4

Very little berries were obtained from the 0 plots on 7. VIII, so that the quality was difficult to judge. From the fertilized plots the largest yield was obtained on that date.

Table 31. Points awarded in sensory tests in 1970 for quality of berries of strains H/A, Lu and P (P_1 and P_2). Unfertilized.

Taulukko 31. H/A-, Lu- ja P (P_1 ja P_2)- kannan marjojen laadun vertailua aistinvaraisesti arvosteltuna v. 1970. Marjat korjattu lannoittamattomilta ruuduilta.

Date of test *Hav. pv.*	Aroma 0–4 *Aromi*		Taste 0–10 *Maku*		Appearance and colour *Ulkonäkö ja väri* 0–2	
	H/A	P_1	H/A	P_1	H/A	P_1
11. VII	2.7	3.5	6.7	7.9	1.5	1.9
20. VII	1.3	3.0	6.9	7.3	1.2	1.5
7. VIII	2.4	2.3	6.9	6.7	1.3	1.4
25. VIII	2.1	3.1	6.9	8.5	1.6	1.9
Mean .... *Keskim.*	2.1	3.0	6.9	7.6	1.4	1.7
	Lu	P_2	Lu	P_2	Lu	P_2
13. VII	3.2	3.2	7.4	8.0	1.7	1.9
22. VII	3.0	3.0	7.7	8.1	1.2	1.5
6. VIII	2.3	2.5	7.9	7.3	1.2	1.6
Mean .... *Keskim.*	2.8	2.9	7.7	7.8	1.4	1.7

IV GENERAL REVIEW OF THE RESULTS

Fruiting of R. arcticus

The investigation of pollination in R. *arcticus* formed an essential part of the biological study of its fruiting. Preliminary experiments undertaken in the years 1940—42 had failed to provide a definite answer to the question whether, and to what extent, self-fertile forms occurred in the different strains of the species. Further investigations were accordingly carried out in the 1960s. Their results indicated that self-fertility is probably extremely rare, since all the strains examined were in effect self-sterile. ČERNOVA (1959) and LARSSON (1969) had also found that R. *arcticus* did not set fruit when its buds were isolated.

Self-sterility was found to result from incompatibility. The pollen failed to germinate on the stigmas of flowers of the same plant or other plants of the same strain. Intraclonal pollination did not prevent the subsequent germination on the same stigma of pollen from another strain. The self-sterility mechanism is thus operative before karyogamy.

The pollination experiments revealed that the strains differed in fertility, both as seed and as pollen parents. Strain P was found to be the most productive as a seed parent, whereas strain H/A was the best pollen parent. Strain Ap was clearly the poorest in both respects.

Convincing proof was obtained that natural pollination is best ensured by growing different strains in close proximity to each other. Even a distance of two metres in a R. *arcticus* crop appeared to be too great.

As is well known, the few R. *arcticus* occurrences in southern Finland flower abundantly but do not fruit. One of the main causes of their failure to set fruit is probably that they each represent a single clone and other populations are too far away. Strain P, which proved to be the most productive in these experiments, did not set fruit in its natural locality at Piikkiö. When planted out beside other strains at Maaninka, it immediately began to fruit abundantly, even being clearly superior to the other strains.

How large the portion of the strain intended as pollen parent should be to ensure a good berry yield has so far not been ascertained. This is not of any practical importance if two equally productive strains are used. Similar amounts of the two strains can then be planted out, either mixed together or in alternate rows. However, the strains should not be mixed together unless they have equally vigorous vegetative reproduction. Differences in this feature have been observed.

Pollination was found to occur mainly through the agency of bumble-bees and honey-bees. The life cycle of bumble-bees is such that they are generally scarce in the early summer. Only fertilized females are able to overwinter, each of them giving rise to its own community in the spring, and the cohorts of early summer do not comprise very many individuals. It is thus probable that, without the aid of honey-bees, the pollination of R. *arcticus* would remain incomplete, especially at the height of the flowering period, which occurs in early summer.

The weather conditions are probably of great importance for the fruiting of R. *arcticus*. SAASTAMOINEN (1930) and KOTILAINEN (1949) suggested that hot weather in the middle of the summer dries up the flowers rapidly before they are fertilized. This also seemed possible in the light of the present study. The occurrence of insect pests, especially during prolonged periods of hot dry weather, was also observed. In nature thrips and beetles probably often decrease the berry yield of R. *arcticus*. They were clearly more abundant in natural than in cultivated communities.

A long period of drought in the beginning or middle of the summer was observed to initiate an ageing process in R. *arcticus* crops, which could not be arrested completely by subsequent rains.

Summers with average precipitation were often good summers for R. *arcticus*. Heavy continuous rainfall clearly interfered with fruiting, presumably partly because pollinating insects are not in flight during rain.

The flowers can also be damaged by frosts. They can stand two or three degrees of frost on one single occasion, but are damaged by several successive nights of frost, even though the temperature does not sink far below freezing-point. Temperatures below —4 °C apparently kill the flowers in one single night.

Since R. *arcticus* generally flowers throughout the summer, frosts occurring in early summer cannot destroy the whole of the berry yield, as often happens, for example, with the cloudberry. However, flowering is at its maximum in early summer, so that frosts can cause a considerable loss. ČERNOVA (1959) reports that even temperatures of 2—5 °C prevailing for a long time in the spring prevent the germination of the pollen and damage the stigmas of R. *arcticus*.

In other respects, the length of the flowering and fruiting period (2—2 1/2 months) may be considered one of the disadvantageous features of R. *arcticus*.

Cultivation of R. arcticus

The soil type and acidity of the substrate were not found to be of importance for the cultivation of R. *arcticus*. The practice of covering the soil surface to keep the fruit clean also prevents the evaporation of moisture from the soil. Thus even rather heavy soils presumably remain sufficiently penetrable to allow the root system to spread. Natural uncovered clay soils, or soils with a large clay fraction, that tend to crack as they dry out are not suitable for R. *arcticus*.

The level of the water table may be of

importance when R. *arcticus* is cultivated on peatland. Partially humified peat is too porous for the ground water to be drawn upwards by capillarity. If the water table is not sufficiently high, R. *arcticus* is completely dependent on rain-water. On the other hand, it is also harmful to R. *arcticus* for the water table to be too near the soil surface; in damp habitats in nature the plant often grows on hummocks. The shoot system appeared to develop readily on peat substrates, even becoming too dense, which was clearly to the disadvantage of the berry yield.

The care of the soil surface is an important and costly part of the cultivation of R. *arcticus* (weed control and covering materials). It is therefore desirable to use the cultivated area to the full. Large intervals between the rows, as, for example, the two metres suggested by LARSSON (1955), cannot be recommended. In any case, even large distances will not prevent the eventual mingling of the strains, if subterranean partitions are not employed, and this scarcely has any significance in practical cultivation. Row intervals of 1—1.2 m were found to be suitable. The plants can then be tended and the berries picked from paths made between the rows.

As was pointed out in the section on the biology of R. *arcticus*, if fruiting is to be ensured, at least two different strains must be grown close to each other, for example in alternate rows. It also appears to be desirable to keep bees in the neighbourhood, in order that the plants may be properly pollinated.

It is inevitable to cover the soil surface for keeping the berries clean. The choice of cover will partly depend on the materials available in each particular locality.

The covering materials presented in Table 14 (p. 44, sawdust, peat, sand, fresh sphagnum moss) were found to have some unfavourable properties. The sawdust rather readily became mouldy and also occasioned symptoms suggestive of some disease in R. *arcticus*. It also had some tendency to adhere to the berries. Peat also adhered to the berries and, in addition, attracted the roots of the plants to the surface layer, where there was danger of drying out. Both these observations were also made in respect of the sand, which had not been sifted and contained dust. The sand also became hot during warm weather, which may have an adverse effect on fruiting, since it presumably accelerates the withering of the flowers. Nor is the increase in soil temperature occasioned by a covering of sand likely to be of much benefit to R. *arcticus*. Fresh sphagnum moss may perhaps be considered the best of these materials. It is very possible that the evaporation during dry weather of rain and irrigation water retained by a thick sphagnum moss cover increases the humidity of the air near the ground and thus promotes the fertilization of the flowers.

All the covering materials presented in Table 15 (p. 45, gravel, Leca gravel, fresh sphagnum moss, wood chips, tree bark) can be employed for that purpose. The suitability of gravel is probably considerably impaired by its tendency to become hot. Leca gravel has somewhat the same property, but is most easily applied, being so light that it may even be washed away from sloping surfaces by heavy rains. Wood chips were also found to displace, in some degree. Fresh sphagnum moss is the most laborious to lay down.

When tree bark is used, changes may be expected in the nutrient status of the substrate. As the bark decays, it uses nutrients contained by the soil. Wood chips probably do not require such nutrients to the same extent, or at least do not utilize them so rapidly. Gravel, Leca gravel and sphagnum moss do not exert this effect. It might also be worthwhile to try covering the soil surface with fresh conifer branches cut to short lengths.

It is not advisable to allow R. *arcticus* to form a continuous dense carpet. This could be prevented by scattering the soil cover with, e.g. pieces of plank of a suitable size, say 2—3 dm^2 in area, placed out at certain intervals. This question has not yet been studied more closely.

In their experiments at Köyliö, ERVI et al. (1955) obtained successful results with a 10—20-cm-thick cover composed of chopped straw and fresh hay. The cover smothered other plants and greatly benefited R. *arcticus*. It was also found to shield the lower parts of R. *arcticus* on cold summer nights, and afforded effective protection in the winter. This type of cover was not tried in this study. It would presumably be beneficial during dry summers, like the cover of cut grass recommended by LARSSON (1955).

The control of the weeds growing together with R. *arcticus* was investigated in various herbicide experiments, but so far no satisfactory solution has been obtained. It is thus particularly important to destroy perennial weeds before R. *arcticus* is planted out. Quick grass can be controlled with TCA in the preceding autumn. Seed-propagated weeds can be effectively destroyed by shielding the cultivated plants and spraying the empty spaces around them with paraquat. Root-propagated weeds can be treated individually with, for example, hormone preparations. Otherwise weeding must be done as yet by hand.

The results obtained with herbicides obviously depend closely on the time and rates of application. Further research on this subject is required. In particular, the possibility of employing chloroxuron (Teneran), lenacil (Venzar) and terbacil (Sinbar) should be investigated.

The control of insect pests is complicated by the fact that R. *arcticus* bears flowers and ripe berries at the same time. The duration of the toxic effect of the pesticide should thus be as short as possible, a few days at most. The methods of control should also be harmless to bumble-bees and honey-bees.

In the meantime, the only insecticides which can be used without restrictions are pyrethrin aerosols, and even these should not contain any substances which are toxic to bees. Before other insecticides can be employed, these should be provided with instructions for their use with R. *arcticus*.

The requirements of plants for fertilizers are generally difficult to determine exactly. The soil already contains nutrients, and their amounts vary in different parts of the field. It has been observed, particularly in young, just spreading R. *arcticus* crops, that the application of fertilizer, especially nitrogen, easily causes excessively luxuriant growth, at the expense of the berry yield.

LARSSON (1955) recommends the use of sulphur-containing fertilizers, ammonium sulphate and potassium sulphate, both to be applied at a rate of 1 kg/are. She considers phosphates unnecessary. Her observations (1970) indicated that fertilizers should be applied in the autumn, since the delicate buds may be harmed if given in the spring.

Experience so far obtained suggests that it is safest to plant out R. *arcticus* in soil of good nutrient status. The beneficial effect of the fertilizer is evidently best directed to fruiting when the R. *arcticus* crop is some years old and precipitation is low. This was indicated by fertilizer experiments IV and V (pp. 56—58). The Garden Super Y fertilizer (11—11—22) used in these experiments has a rather high nitrogen content. Fertilizer mixtures containing less nitrogen, such as Chlorine-free Super Y fertilizer (7—24—14), would perhaps be more suitable, especially when applied at higher rates. The trace elements contained by fertilizer mixtures may benefit R. *arcticus*.

The berry yields varied widely from year to year. During the period 1935—59, it was observed that summers in which the precipitation was clearly greater than normal gave poor berry yields. Poor yields were also obtained when there were long, unbroken periods of hot, dry weather.

Comparisons of the different H strains during the above-mentioned years showed that H/A was clearly the best. When new material was examined in the 1960s, strain P proved almost without exception to be markedly more productive than all the other strains, including H/A.

The yields in the 1960s were generally most abundant in the third or fourth year including the planting year when the spreading crop had just filled up the cultivation area. When all the growing space had been occupied, the yields dropped sharply.

One of the best of the annual yields was that of strain P in 1963, 67 kg/are; the yield of the best of the replicate plots was then 96 kg/are (experiment VIII, p. 52). The best yields were generally 40—60 kg/are. The highest total yield for the three years following the year of planting out was 118 kg/are. This was obtained from strain P in the years 1961—63. Most of the yields of the other strains were much smaller.

Crops of R. *arcticus* should be renewed at intervals of four to five years. This was best accomplished by planting. Rotation cultivation should be practised, since R. *arcticus* did not seem to thrive in places in which it had just been growing, even although the old vegetation had been cleared away and fertilizer applied.

Another reason for rotation is in this way to prevent populations arising from seed, since the soil before will not contain seeds of R. *arcticus*. Seedlings are not desirable in the crops, as they are not of uniform quality, and many are inferior to the parents. It is, however, not possible completely to prevent plants originating from seed from growing up in the crops over the years. Berries are missed during the picking and after two or three years flowering and fruiting individuals have developed from the seeds. The greater part of the delicate seedlings will not reach maturity, but some will survive.

Good material is obtained for renewing the crops by propagating the best plants in earlier cultivated areas. The plants spread very rapidly if they are provided with sufficient space. The berries should be carefully removed during propagation, and will in any case be very scarce if individuals of different origins are planted out apart from each other.

Favourable cultivation sites for R. *arcticus* are moist fields beside lakes where frosts seldom occur during the prowing season. Other suitable sites are gentle slopes with moist soil and good protection from the wind and frosts. A long, thick snow-lie is evidently very important, to prevent growth from commencing too early in the spring. ČERNOVA (1959) reports that overwintering buds of R. *arcticus* lying within a 1—2-cm thick crust of ice below the snow have woken to life at a temperature of 0 °C, the ice beginning to melt around the buds.

Quality of the berries of R. arcticus

In the preliminary investigation of the quality of the berries, the results of the sensory and chemical tests were found to support each other.

Aroma and taste were best in the ripe berries. Aroma and colour were somewhat improved by a short period of storage if the berries were picked when half-ripe, but deteriorated if picked ripe. The picking of the berries of R. *arcticus* is time-consuming and the fruiting season is lengthy, so that it would be advantageous to increase the intervals between picking. The picking of half-ripe berries is not desirable, but may be unavoidable in practice. It is even less desirable to include over-ripe berries in the harvest.

The application of fertilizer weakened in some degree the taste of the berries, reducing the sugar content. This effect was relatively greater at the higher than at the lower rate of application. The presence of nutrients in the right proportions may be of importance for keeping the taste good.

The strains subjected to chemical analyses and sensory tests showed the same sequence in both cases when arranged in descending order of merit in respect of aroma and taste: P, Lu and H/A. Strain P was also judged to be the best in respect of appearance and colour.

The storage experiment showed that the nectarberry resembles the strawberry and the raspberry in its poor tolerance of storage. Berries picked while still slightly immature kept fairly well for two or three days, when stored in a cool place, but ripe berries began to deteriorate within twenty-four hours of picking. Low temperatures retarded changes to some extent.

The berries were found to be suitable for deep-freezing.

On the initiative of Prof. J. E. Hårdh, gas-chromatographic analyses were carried out at the Department of Horticulture of the University of Helsinki, in 1965, on strains H/A, H/D, Hä, Le and P, obtained from the North Savo Agricultural Experiment Station. The results (not published) showed that each of the strains contained small quantities of acetic acid and methylester. The peak representing ethanol was larger than the others and rose steadily with increasing ripeness. There were some differences between the R. *arcticus* strains, chiefly in the ratios of the peaks to each other.

It also may be mentioned that thorough investigations on the aroma of R. *arcticus* berries are now in progress at the University of Turku (KALLIO, H. and LINKO, R. R. 1972).

V SUMMARY

The berries of *Rubus arcticus* L. (called the arctic bramble or arctic raspberry but in the author's opinion more suitably named the nectarberry), have a particularly fine flavour. In Europe, the species is mainly distributed between 60° and 70° N latitude in Fennoscandia, being most abundant in Finland. It has been generally observed to be declining in nature, and the supply of its berries is dwindling.

The North Savo Agricultural Experiment Station is situated in the optimal area for the occurrence and fruiting of R. *arcticus*, at about 63° N latitude. Here the experimental cultivation of R. *arcticus* was begun in 1933, with material collected from nature in the immediate surroundings of the station. In the 1960s this stock was supplemented with experimental material collected all over Finland.

Biology

R. *arcticus* generally begins to flower towards the end of May and continues throughout the summer. Flowers are developed in great quantity during the course of the summer. In 1968 their average number was found to be 1350/m^2, although flowering ceased earlier than usual in that year, in the first half of August.

The average diameter of the flowers was 23.5 mm, the range of variation among the individual flowers (1440 measured) being 13—36 mm. The number of petals varied with the individual from 4 to 14, the average number being 6.5.

For practical purposes, R. *arcticus* may be regarded as self-sterile. Not one of the 12 strains included in the pollination experiments was found to be self-fertile. The self-sterility was found to result from incompatibility of the sporophytic-gametophytic type. The flowers were not fertilized by their own pollen or that of the plants of the same strain. In contrast, all 12 strains were able to fertilize each other. When used as a seed parent, strain P was found to produce most fruit. The best pollen parent proved to be strain H/A.

Natural pollination is best ensured by planting different strains close to each other, e.g. in alternate rows. The chief pollinating agents are bumble-bees and honey-bees. Smaller insects did not seem to be sufficiently efficient pollinators.

The flowers of early summer set the most fruit. The weather conditions prevailing during the growing season are of great importance for fruiting. Continual rain or long periods of hot and dry weather have an adverse effect. Moreover the number of flowers setting fruit may be decreased by spring frosts. The flowers can survive two or three degrees of frost for a single night, but die if the temperature sinks below —4 °C.

On average, the berry of R. *arcticus* contained 20—35 drupelets (seeds). Its average weight was ca. 1 g. The largest berry obtained in the experiments weighed 4.6 g, and the largest number of drupelets observed in any one berry was 101. The berry is tightly attached to its base, from which it does not loosen, even when ripe. The base, consisting of the receptacle and the calyx, was found to constitute from 2.5 to 5 % of the weight of the berry varying with the strain. The proportion of the weight of the berry relating to the seeds was about 5.5 %.

Cultivation

The roles played by the type of soil and particularly the acidity of the substrate are not decisive. R. *arcticus* grew well on substrates whose pH ranged from 3.20 to 6.35. Soil moisture and atmospheric humidity are more important factors.

Garden Super Y fertilizer (11—11—22) given at rates of 4 and 8 kg/are clearly increased the berry yield and the size of the berries. The fertilizer was applied to crops some years old and already covering the whole cultivation area.

Intervals of 1—1.2 m can suitably be left between the rows. The intervals between the plants depends upon the planting material. Plants with a lump of earth adhering to the roots can be set out at intervals of 20—30 cm. When planting material is taken from a growing crop, it is suitable for planting out in a continuous row.

Covering the surface of the soil appeared important for keeping the berries clean and preventing the evaporation of soil moisture. Among the covering materials found to be useful were fresh sphagnum moss (perhaps the best), wood chips, and light building gravel (Leca II).

Crops deteriorated rapidly once they had covered the whole of the spaces between the planted rows. They should therefore be renewed at intervals of four to five years. Rotation cultivation seemed to be necessary, since R. *arcticus* did not thrive in sites from which it has just been removed.

Strain H/A was found to be the most productive in the experiments carried out in the years 1933—59. In later experiments, 1960—70, strain P was clearly superior to the other strains. The largest yields were obtained two to three years after planting out, by which time R. *arcticus* had spread about all over the area, but had not yet become too dense. The best yields were then about 40—60 kg/are.

The harvesting of the berries is time-consuming. The average rate of picking was 809 g/hr. The best result was ca. 2 kg/hr. The harvesting time is about two months.

Quality of the berries

Preliminary investigations of the quality of the berries revealed differences between the strains in the content of soluble dry matter (sugars) and the acid content. Strain P had the highest content of soluble dry matter, strain H/A the lowest. The converse was the case, as regards the acid content.

An increase in the rate of fertilizer application decreased the content of soluble dry matter, which weakened the taste of the berries.

The aroma and colour of half-ripe berries improved somewhat during short storage, but did not attain the standard of fully ripened berries.

The berries were found to be highly perishable. If picked when ripe, they began to deteriorate within 24 hours. The berries were found to be suitable for deep-freezing.

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REFERENCES

ANON. Official methods of analysis of the association of official agricultural chemists. 10 Ed. 1965. 955 p. Washington.

ARASU, N. T. 1968. Self-incompatibility in angiosperms: a review. Genetica 39: 1—24.

BOUYOUCOS, G. J. 1954. New type electrode for plaster of Paris moisture blocks. Soil Sci. 78: 339—342.

ČERNOVA, E. P. 1959. Poljanika (*Rubus arcticus* L.) i jejo vvedenie v kulturu. Akademija Nauk SSSR. Botaničeskij Institut im V. L. Komarova. 34 p. Moskva & Leningrad.

EICHWALD, K. 1959. Die Untergattung der Brombeeren *Cylactis* Rafin. Untersuchung der Phylogenie einer borealen Phlanzengruppe. Zusammenfassung. Tartu Riikl. Ülik. Toimet. 81: Bot.-alased tööd 2: 253—283.

— 1970. Taimeharuldused ja nende kaitse probleeme tänapäeval. Kodumaiste taimede kasutamisest haljastamisel. Eesti NSV teaduste akadeemia looduskaitse komisjon. Tartu, p. 30—41.

EILART, J. 1965. Mesimurakas. Eesti Loodus 1: 38.

ERVI, L. O., HANIOJA, P. & KIVINEN, E. 1955. Mesimarjan (*Rubus arcticus* L.) marjontaa koskevia tutkimuksia. Acta Agr. Fenn. 83: 93—112.

FREINDLING, M. V. 1949. Polenika (*Rubus arcticus* L.). Neuvostoliiton tiedeakatemian Karjalais-suomalaisen filiaalin Tied. 3: 49—57. Leningrad.

HARLEY, R. M. 1956. *Rubus arcticus* L. in Britain. Watsonia. J. Bot. Soc. of the British Isles. Vol. 3, Pt. 5: 237—238.

HIIRSALMI, H. 1969. Marja- ja hedelmäkasvien jalostustoiminta Puutarhantutkimuslaitoksessa. Ann. Agric. Fenn. 8: 133—148.

HULTÉN, E. 1971. The circumpolar plants. II. Dicotyledons. Kungl. Sv. Vet. Akad. Handl. 4. Ser. 13, 1: 164—165, 373—375.

JOSLYN, M. A. 1970. Methods in food analysis. Physical, chemical and instrumental methods of analysis. 2nd Ed. 845 p. New York & London.

KALLIO, H. & LINKO, R. R. 1972. Volatile carbonyl compounds in *Rubus arcticus* determined as their 2,4-dinitrophenylhydrazones by gas-liquid chromatography. Short communication of the 3rd Nordic Aroma Symp., June 6—8, 1972, Hämeenlinna, Finland. Sponsored by Nordforsk.

KALLIO, T. K. 1971. Havaintoja mesimarjan taimien lisäämisestä. Puutarha 74: 627—628.

KOTILAINEN, M. J. 1949. Luonnonkasvien hallavaurioista. Suom. Tiedeakatemian esitelmät ja pöytäkirjat. 1948: 137—153.

LAGERBERG, T. 1939. *Rubus arcticus* L. Pohjolan luonnonkasvit: 717—719.

LARSSON, E. G. K. 1955. Odlingsförsök med åkerbär, *Rubus arcticus*. Sver. Pomol. För. Årsskr.: 183—195.

— 1957. Tetraploid *Rubus arcticus*, framställd genom colchicinbehandling. Bot. Not. 110: 152—159.

— 1968. Betydelsen av vildväxande nordliga *Rubus*-arter för framställning av nya bärsorter. Sv. Naturvet. 21: 106—109.

— 1969. Experimental taxonomy as a base for breeding in northern Rubi. Hereditas 63: 283—351.
— 1970 a. Nordiska *Rubus*-arters värde för växtförädling och odling. Frukt og baer, Hedelmät ja marjat. Nord. Årsskr., Pohjoism. Vuosik., p. 11—14.
— 1970 b. Utveckling och odling av nordliga bärtyper inom släktet *Rubus* L. Akademisk avhandling, Lantbr.högsk. Diss. 75, 19 p. Piteå.
LEVIN, G. M. 1961. Polenika. Priroda 50: 114—115.
LINDGREN, E. & RINGIUS, L. A. 1868. Odling af bärfrukter. Trädgårdsbok för Norden omfattande anvisning till odling af de för nordliga delarne af Sverige och Finland lämpliga matväxter. Åkerbär, p. 44—47. Stockholm.
LINNAEUS, C. 1762. Åkerbärs plantering. Kongl. Vet. Acad. Handl. 23: 192—197.
RYYNÄNEN, A. 1971. Mesimarjan viljely. Erip. Kansallis-Osake-Pankin kuukausikats. 4/71. 12 p.
— 1972. Arctic bramble (*Rubus arcticus* L.), a new cultivated plant. Ann. Agric. Fenn. 11, 3: 170—173.
SAASTAMOINEN, S. 1930. Mesimarja (*Rubus arcticus* L.) Suomessa. Ann. Soc. Zool.-Bot. Fenn. Vanamo 13: 355—414.
SALMINEN, M. 1948. Sisä-Suomen mahdollisuuksista puutarhatuotantoon. Maatal. ja Koetoim. 3: 68—91.
STEEL, R. G. D. & TORRIE, J. H. 1960. Principles and procedures of statistics. 481 p. New York.
TAMMISOLA, J. & RYYNÄNEN, A. 1970. Incompatibility in *Rubus arcticus* L. Hereditas 66: 269—278.
TILGNER, D. J. 1962. Dilution tests for odor and flavor analysis. Food Technol. 16: 26—29.
— 1965. Flavor dilution profilogram. Food Technol. 19: 25—29.
VAARAMA, A. 1965. *Rubus arcticus* L. — Mesimarja. Suuri Kasvikirja II: 750—754. Helsinki.
ZELLER, O. 1964. Entwicklungsmorphologische Studien an Blütenknospen von *Rubus arcticus* L. und *Rubus chamaemorus* L. in Finnland. Sonderdruck aus Beiträge zur Phytologie, 18 p.

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SELOSTUS

Mesimarja (Rubus arcticus L.) ja sen viljely

ANNIKKI RYYNÄNEN

Maatalouden tutkimuskeskus, Etelä-Savon koeasema, Karila, Mikkeli

Mesimarja (*Rubus arcticus* L.) on tunnettu hienonmakuisista marjoistaan. Mesimarjan levinneisyysalue Euroopassa käsittää pääasiassa 60. ja 70. leveysasteen välisen alueen Fennoskandiassa. Runsaimmin mesimarjaa esiintyy Suomessa. Mesimarjan väheneminen luonnossa on pantu yleisesti merkille. Marjojen saanti on käynyt miltei harvinaiseksi.

Mesimarjalla on maassamme selvä optimialue, missä se esiintyy yleisemmin ja marjoo runsaammin kuin muualla. Tämä alue käsittää noin 62. ja 66. leveysasteen välisen kaistan maamme keskiosan yli. Maatalouden tutkimuskeskuksen Pohjois-Savon koeasemalla Maaningalla, joka sijaitsee kyseisellä optimialueella, todettiin mesimarjan väheneminen luonnossa 1930-luvulla, jolloin maisteri Martti Salmisen toimesta pantiin alulle mesimarjan viljelykokeilut lähiympäristöstä kerätyllä mesimarja-aineistolla. Tutkimukset keskeytyivät sotien aikana ja saatiin uudelleen käyntiin 1960. Tällöin koemateriaalin muodosti ympäri Suomea kerätty mesimarja-aineisto täydennettynä entisillä kannoilla sekä myöhemmin risteytystuloksina saadulla varsin runsaalla yksilömäärällä.

Tämän tutkimuksen tarkoituksena oli selvittää mesimarjan biologiaa yleensä ja erityisesti marjomisen edellytyksiä eri kannoilla. Samanaikaisesti pyrittiin selvittelemään viljelyyn liittyviä kysymyksiä, kuten maalajia ja maan happamuutta, istutusaikaa ja -tapaa, maanpinnan hoitoa, kasvinsuojelua ja lannoitustarvetta. Myös selviteltiin alustavasti marjan laatua.

Tutkimukset jatkuivat Pohjois-Savon koeasemalla vuoteen 1970. Sen jälkeen katsottiin voitavan aloitella käytännön viljelyä. Mesimarjan valvottuja havaintoviljelyksiä perustettiin vuosina 1969—71 eri puolille maatamme noin 30. Valikoidun kantamateriaalin vertailututkimukset jatkuvat vuodesta 1971 Etelä-Savon koeasemalla ja Puutarhantutkimuslaitoksella. Samoin suoritetaan edelleen lisäselvityksiä mm. lannoitusta ja kasvinsuojelua koskevissa kysymyksissä.

Biologia

Mesimarjan kukinta alkaa yleensä touko—kesäkuun vaihteessa ja jatkuu koko kesän. Kukkia kehittyy kesän kuluessa runsaasti. Vuonna 1968 laskettiin niitä kehittyneen keskimäärin 1350 kpl/m^2, vaikka kukinta päättyi silloin normaalia aikaisemmin, jo elokuun alkupuolella.

Mesimarjan kukkien keskimääräinen halkaisija oli 23.5 mm vaihdellen yksittäisissä kukissa (mitattu 1440 kukkaa) 13—36 mm:iin. Terälehtiä oli keskimäärin 6.5 kpl ja vaihtelu yksittäisissä kukissa 4—14 kpl.

Mesimarja on käytännöllisesti katsoen itsesteriili. Oma tai samaa kantaa olevan yksilön kukasta peräisin oleva siitepöly ei hedelmöittänyt. Pölytyskokeissa mukana olleista 12 kannasta ei yksikään osoittautunut itsefertiiliksi. Sen sijaan ne kaikki pystyivät hedelmöittämään toinen toisensa. Itsesteriiliyden todettiin johtuvan inkompatibiliteetistä, vieroksumisesta. Tutkimuksissa käytetyt kannat merkittiin kirjaimilla, jotka viittasivat niiden alkuperäiseen löytöpaikkaan. Kanta P, joka oli peräisin Piikkiöstä, osoittautui emiyksilönä parhaaksi marjojen muodostajaksi, kanta H/A, joka oli Halolan koeaseman alueelta, todettiin parhaaksi pölyttäjäksi.

Pölyttymisen varmistamiseksi luonnollisen pölytyksen tapahtuessa todettiin tärkeäksi, että toisilleen vieraat kannat kasvoivat lähellä toisiaan, esimerkiksi vuororivein istutettuina. Pölytyksen suorittivat pääasiassa kimalaiset ja mehiläiset. Niitä pienemmät hyönteiset eivät näyttäneet pystyvän siihen riittävän tehokkaasti.

Marjominen oli parhainta alkukesän kukinnasta. Kasvukauden sääoloilla on huomattava merkitys marjojen muodostumiselle. Keväthallat voivat palelluttaa aikaisimmat kukat. Mesimarjan todettiin kestävän parin kolmen asteen hallan yhtenä yönä, mutta useamman perättäisen yönseudun alhainen lämpötila oli tuhoisa. Myös yhtämittaiset sateet tai toisaalta pitkät poutaiset hellekaudet häiritsevät pahoin marjomista. Parhaita mesimarjakesiä ovat olleet sateisuudeltaan ja lämpösuhteiltaan keskimääräiset kesät.

Mesimarjan marjassa oli lohkoja (siemeniä) keskimäärin 20—35 kpl. Suurin kokeissa tavattu lohkomäärä oli 101. Marjan keskipaino oli 1 g. Suurimmat kokeista korjatut marjat painoivat yli 4 g, suurin 4.6 g.

Marja on tiukasti kiinni kannassaan, niin ettei se irtoa siitä kypsänäkään. Kannan, jonka muodostavat kukkapohjus ja verhiö, osuus marjan painosta vaihteli eri kannoilla n. 2.5—5 %:iin. Siementen osuus marjan painosta oli n. 5.5 %.

Viljely

Kasvualustan maalajilla ja varsinkaan happamuudella ei todettu olevan merkitystä. Mesimarja kasvoi hyvin pH-alueella 3.20—6.35. Sen sijaan sekä maan että ilman kosteus ovat tärkeitä. Mesimarja viihtyy kostealla, mutta ei märällä kasvupaikalla.

Mesimarjan kasvualustan tulisi olla monipuolisesti ravinnerikas. Runsas väkilannoitteiden käyttö mesimarjakasvustolle saattaa kuitenkin olla haitallista. Mesimarjan istutus ennestään hyvässä kasvukunnossa olevaan maahan on tähänastisen kokemuksen mukaan varminta. Nuoren kasvuston ollessa parhaillaan leviämässä rivien väleihin nimenomaan typpilannoitus helposti rehevöittää kasvua liiaksi marjomisen kustannuksella. Kun kasvusto oli jo varttunutta parin kolmen vuoden kuluttua istutuksesta, saatiin lannoituskokeissa varsin selviä sadonlisäyksiä käyttämällä 4 ja 8 kg/a puutarhan super-Y-lannosta. Yleensä kloorivapaat Y-lannokset, jotka sisältävät myös hivenravinteita, ovat sopivia. Lannoituksessa voitaneen vuosittain käyttää vain pienehköja (3—4 kg/a) määriä, niitäkin joko aikaisin keväällä tai jo edellisenä syksynä.

Sopivaksi riviväliksi osoittautui 1—1.2 m. Juuripaakun kanssa istutettaessa taimivälit voivat olla 20—30 cm. Kasvavasta kasvustosta otettua istutusmateriaalia käytettäessä istutus voidaan suorittaa yhtenäiseen, noin 15 cm syvään vakoon irroittamatta versoja yksittäisiksi taimiksi. Liikkuminen alueella tapahtuu polkuja pitkin rivien keskiväleissä.

Marjojen multaantumisen estämiseksi todettiin maanpinnan peittäminen välttämättömäksi. Samalla estyy tai ainakin hidastuu myös kosteuden haihtuminen maasta. Sopiviksi katemateriaaleiksi havaittiin mm. tuore rahkasammal, puuhake ja kevyt rakennussora (Leca II).

Mesimarjaviljelys taantuu nopeasti sen jälkeen, kun kasvusto peittää koko rivivälit. Viljelyksen uusiminen tulee ajankohtaiseksi 4—5 vuoden välein. Kun mesimarja ei entisellä kasvupaikalla välittömästi menesty, on viljelykierron käyttäminen välttämätöntä. Se on tarpeen myös maan kunnostuksen ja monivuotisten rikkakasvien torjunnan kannalta.

Vuosien 1933—59 kokeissa oli H/A -kanta (= 'Mesma' eli toinen niistä kahdesta lajikkeesta, joiden taimet tulivat myyntiin keväällä 1972) satoisin. Myöhemmissä (1960—70) kokeissa oli P-kanta (= 'Mespi', toinen viljelylajike) selvästi kaikkia muita kantoja parempi. Parhaimmillaan sadot olivat 2—3 vuoden kuluttua istutuksesta, jolloin kasvusto oli levinnyt yli alueen, mutta ei ollut vielä ylitiheää. Tällöin parhaat sadot olivat noin 40—60 kg/a.

Marjojen poiminta on hidasta. Keskimääräinen poimintanopeus oli 809 g/tunti. Paras tulos oli n. 2 kg/tunti. Satokausi kestää n. 2 kk.

Marjojen laatu

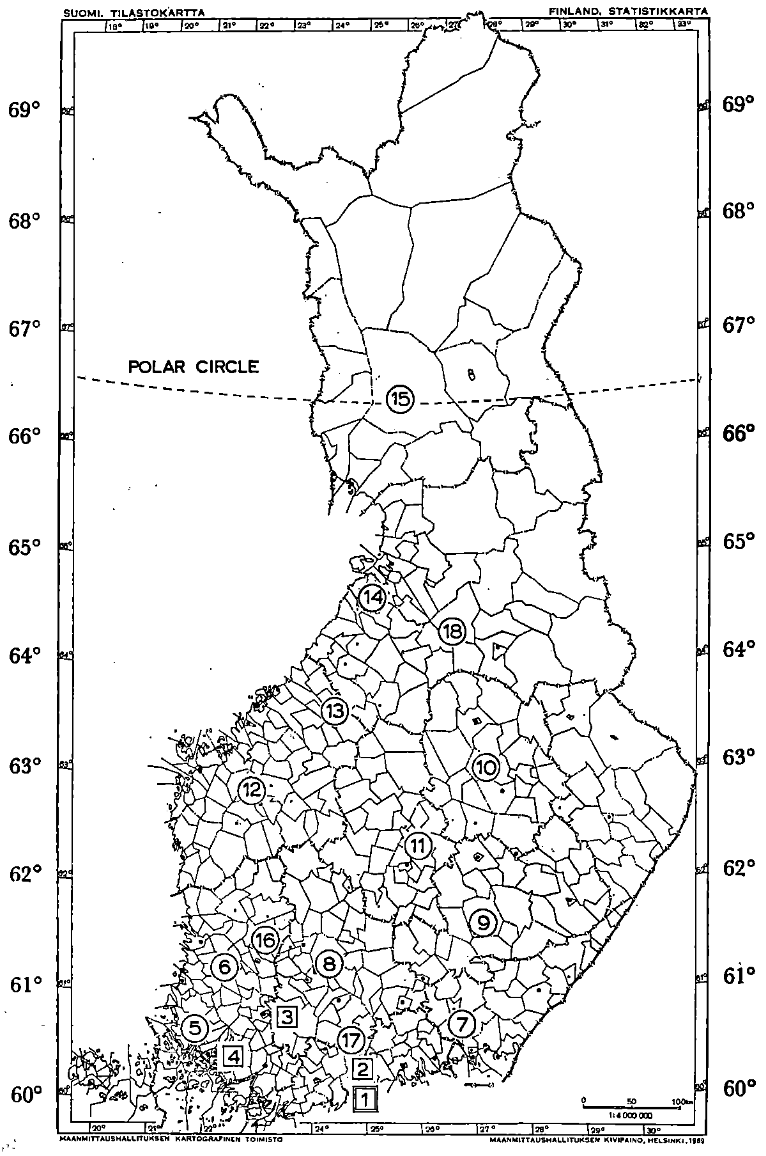
Marjojen alustavia laatututkimuksia suoritettaessa todettiin, että kantojen (mukana kannat H/A, Lu ja

P) välillä oli eroja liukoisen kuiva-aineen (sokerien) määrissä sekä happoisuudessa. Liukoista kuiva-ainetta oli eniten P-kannassa, vähiten H/A -kannassa. Happoisuudessa järjestys oli päinvastainen.

Lannoitus, nimenomaan runsaammin käytettäessä, alensi liukoisen kuiva-aineen määrää ja heikensi täten marjojen makua.

Puolikypsissä marjoissa aromi ja väri kehittyivät jonkin verran säilytyksen aikana, mutta kypsinä poimittujen tasoa ei saavutettu.

Mesimarjojen säilyvyys todettiin heikoksi. Kypsinä poimitut marjat alkoivat huonontua jo poimintavuorokauden aikana varsinkin lämpimässä. Mesimarja osoittautui käytännössä pakastukseen soveliaaksi.



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