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ON BASIS OF THE INVESTIGATIONS CONDUCTED IN THE YEARS 1943–1948

HILKKA SUOMELA

SELOSTUS:
KUMIVOIKUKAN VILJELYMAHDOLLISUUKSISTA SUOMESSA VUOSINA 1943—1948 SUORITETTUJEN TUTKIMUKSIEN PERUSTEELLA.

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Helsinki 1950. Valtioneuvoston kirjapaino

Preface.

The present investigation was begun on the initiative of the Agricultural Research Institute and the head of its Department of Plant Husbandry, Professor OTTO VALLE, and the financial aid given by Suomen Gummitehdas Oy. enabled me to carry it out.

I am greatly indebted to my teacher and principal, Professor OTTO VALLE for his guidance, his encouraging support and valuable advice during several years.

I also want to thank Professor J. O. SAULI for the sympathy he has shown with my work and the trouble he has taken in reading the manuscript.

I express my thanks to Suomen Gummitehdas Oy., its General Director T. WESTERLUND, Councillor of mining, and its Technical Manager E. LILJEROOS, Councillor of mining, for the great financial aid which has enabled me to carry out this investigation and get it printed. Especially I want to thank Mr. E. LILJEROOS, Councillor of mining, for his great interest in my work during several years.

I am indebted to Miss ELLI AUTERINEN, graduate in engineering, who in 1943—44 conducted the determinations of rubber contents and tested the quality of kok-saghyz rubber placing the results at my disposal. I also want to thank her for the valuable advice I received from her when I began to conduct the determinations of rubber contents myself in 1945.

Besides, I want to thank Professor J. KERÄNEN, who has made the necessary meteorological observations available, Professor J. A. JAMALAINEN for his assistance in translating Russian literature, Mr. J. PAATELA, D. Agr. for reading the manuscript, Mr. H. ROIVAINEN, M. A. for taking many of the included photographs, Miss ARMI AILAS, M. A. for translating the manuscript into English, Miss ANNA-LIISA JUVANOJA, B. Agr. for her assistance in finishing the work, and my husband SAMULI SUOMELA, B. Agr. who, in spite of his own research work, has found time to read the manuscript and to make many valuable comments on it.

I also want to express my appreciation to farmers, Experiment Stations, and to all those who in some way or other have assisted me during my investigations.

Tikkurila, November 12th 1949.

Hilkka Suomela.

Contents.

Introduction.

Rubber is a plant product formed in the tissues, most commonly in the latex tubes, of certain plant families and appearing as an emulsion in the latex. There are hundreds of species of rubber-bearing plants, but only the rubber produced in some trees or lianes growing in the tropics has been exploited, whereas the exploitation of herbaceous plants and shrubs has been considered uneconomic. Most of the rubber in the world trade has been obtained from the hevea plants of the tropics.

As raw-material for industries rubber has been used since the beginning of the nineteenth century, but it was not until the twentieth century that rubber and rubber products have gained a position among the most important articles of the world trade. In the years 1916—20 the total rubber consumption of the world was about 250 000 long tons a year (104, p. 331). After that a sevenfold increase has occurred in the consumption of rubber, which was 1 735 000 long tons in 1947 (including synthetic rubber), and which is still increasing (144; 145). Among the most important rubber-producing areas may be mentioned British Malya, the Netherlands East Indies, Ceylon, French Indo-China, British India, Borneo, Burma, Belgian Kongo and many other areas in the tropics (**44**, pp. 104—105).

When the increasing importance of rubber and the dependence of the countries of the temperate zone on the rubber of the tropics were realized in the twentieth century, extensive investigations were started in order to find a suitable rubber-bearing plant for Europe. These investigations were conducted on the largest scale in U. S. S. R., which had no colonies in the tropics, and which for rubber supplies was therefore wholly dependent on the countries controlling the rubber-producing areas. Several expeditions sought for rubber in the Crimea, Georgia, Azerbaidzhan, Armenia, Turkmen, and in many other regions, including even Manchuria. As a result of these expeditions investigations of the following three plants were started in U. S. S. R. in 1930's: tau-saghyz (*Scorzonea tau-saghyz* LIPSH. and BOSSE), krim-saghyz (*Taraxacum meglorrhizon* var. *gymnanthum* HAND. MOZZ.), and kok-saghyz (*Taraxacum kok-saghyz* ROD.). The lastmentioned of these, kok-saghyz, was before long found to be the plant which seemed to have the best possibilities of thriving in the temperate zone (48, p. 537).

Kok-saghyz or Russian dandelion *(Taraxacum kok-saghyz* RODIN or *T. bicorne* DAHLSTEDT) belongs to the dandelions of *Compositae* family. Its native habitat is in the Tien Shan Mountains, in the Kirghizian republic of Kazakhtan (40°—50° N.L.). According to CHEVALIER (26) the plant was discovered in Turkestan by the French traveller *Quillaume Capus* as early as 1881. The species of the plant was determined in 1906, the name being *Taraxacum bicorne* DAHLSTEDT. Under this name the plant appears in a French collection of plants. The year 1931 is generally considered the year in which kok-saghyz was discovered, but in reality only its rubber-bearing qualities were then discovered. The Russian botanist RODIN (119) determined the species of the discovered plant which was not known in Russia at that time. The valley of Kegen in the Tien Shan Mountains is given as the place of discovery. The name given by RODIN, *Taraxacum kok-saghyz* is now commonly used. Kok-saghyz is the popular name of the plant in its native habitat.

As late as in 1930's new expeditions were undertaken in U. S. S. R. to the same areas as before in order to find new rubber-bearing plants. Some new plants were discovered, but they could not supplant the above-mentioned plants (105, pp. 301—302).

With the outbreak of the war in 1939 the importation of rubber from the tropics met with difficulties or ceased. In most European countries as well as in America this initiated extensive investigations directed towards the rubber-bearing plants discovered in U. S. S. R. At the same time as the rubber-producing qualities of these plants were investigated, new rubber-bearing plants were sought. During the war great attention was also paid to the synthetic production of rubber. Synthetic rubber, however, could not solve the rubber situation, for the production of synthetic rubber was dependent on the supply of coal and petroleum, and costs were high. Besides, in many respects its quality was inferior to that of natural rubber.

As difficulties arose in Finland during the second world war because of rubber shortage, Suomen Gummitehdas Oy. granted funds towards investigations of the possibilities of growing kok-saghyz in Finland. Kok-saghyz was chosen as the object of investigations, because, judging by foreign information, it seemed to have the best chances of thriving in Finland. The investigations were mainly conducted at the Agricultural Research Institute, Department of Plant Husbandry, at Tikkurila.

I. Earlier investigations.

Kok-saghyz is not yet grown as a real crop, except in U. S. S. R., and therefore it is impossible to speak about the expansion of kok-saghyz as a cultivated plant. But it has been widely cultivated for experimental purposes. During this decade the possibilities of growing kok-saghyz have been investigated in different continents and in almost all climatic zones, though most investigations have been conducted in the north temperate zone. The most important countries in which investigations have been carried out and results published may be mentioned here: In Europe U. S. S. R., Germany, Sweden, England, France, and Spain, and in America U. S. A. and Canada.

U. S. S. R.

U. S. S. R. has been the leader of the investigations of kok-saghyz. Kok-saghyz was discovered within the frontiers of this country, and it was found to be a rubber-bearing plant already in 1931, when extensive investigations were immediately directed towards it. Already in 1937 NICHIPOROVICH (96) mentions that the results of three years' scientific work conducted by a special trust »Caouchouc» and by many other research institutes show that it is possible to produce rubber also in temperate climatic zones by growing certain shrubs and herbaceous plants. Kok-saghyz was mentioned among these plants.

Experiments on kok-saghyz were carried out in U. S. S. R. all over the country, including the northernmost parts. Cultivations were established even in Siberia (3, p. 13; 62). In 1936 the area of kok-saghyz plantings was 5 000 hectares, in 1938 20 000 hectares, and in 1940 65 000 hectares. The largest plantings were located in Ukraine, for in 1941 330 000 hectares were in cultivation, and in 1942 it was intended to increase the area to 500 000 hectares (31, pp. 2—3). In 1946 kok-saghyz was grown on about 4 000 farms. The size of these plantings was not given (155, p. 226).

A new five-year-plan has been made in U. S. S. R. in order to intensify the cultivation of kok-saghyz. The goal is to make U. S. S. R. self-sufficient in rubber production (70). It is claimed that already in 1938

U. S. S. R. was 76 % self-sufficient in rubber, mainly owing to native synthetic rubber industry (161, p. 190).

In U. S. S. R. kok-saghyz has been the object of more intensive investigations than any other rubber-bearing plant. Attention has been paid to the development of cultural techniques and to plant breeding as well as many problems related to the biology of the plant.

Among the most important of the investigators on whose trials cultural operations for kok-saghyz are based, may be mentioned LYSENKO (65—70), ALTUKHOV (1—4), MYNBAEV (86—88), POLOVENKO (110—112), KOLESNIK (57), FILIPPOV (37), AVSAREGOV (5; 93) and ZASIADNOKOV (137). Many other investigators have studied some special questions related to the cultivation of kok-saghyz (15; 23; 41; 107; 122; 125). KALINKEVICH (50; 51), DIKUSAR (28), MIKHAILOV (82—84) and NEUMAN (92) have studied the question of fertilization. DROBKOV (29), O. K. and O. E. KEDROV-ZIHMAN (52), and BOROVICK, BERGMAN, and BOROVICK-ROMANOVA (21) investigated the importance of trace elements to kok-saghyz. In 1941 DROBKOV (29) published an investigation of the effect of radio-active substances on the yields of roots and rubber. Also the anatomy (16; 25; 97; 113) and the biology (39; 59; 95; 108; 109) of the plant, especially the synthesis of rubber and its accumulation in the root have received attention (13; 17; 18; 74—76; 94; 99; 114—118; 125; 135).

The breeding of kok-saghyz, too, has been investigated in U. S. S. R. KOSTOFF and TIBER (61) published in 1939 the first information concerning the tetraploid kok-saghyz obtained by treatments with colchicine. NAVASHIN and GERASSIMOVA (90) obtained favourable results in their experiments with tetraploid kok-saghyz plants. With regard to breeding the best results, however, have been obtained by using pedigree selection (36; 62; 71; 77; 93; 121). To some extent the kok-saghyz strain improved by BULGAKOV in 1945 is evidently used in U. S. S. R. (93). But it may be concluded from the literature on kok-saghyz that at least up to the year 1947 unimproved seed was most commonly used.

Very little information as to the average yields of roots and rubber in U. S. S. R. has been available. ALTUKHOV (1, ref. 133, p. 11) mentions in 1939 that for many years the average yield of rubber from first year plantings was 20 kg. per ha. In 1938, according to MYNBAEV (86) the average yield of fresh roots for the whole of U. S. S. R. was 1 700 kg. per ha. from first year stands, and 4 200 kg. from second year stands. The corresponding figures for 1939 were 2 000 and 3 800 kg. per ha. Rows were spaced 44.5 cm. apart and seed was sown at the rate of 3 kg. per ha. AVSAREGOV (5, p. 55) mentions that in the regions near Kursk the average yield of fresh roots from first year stands was in the years 1937—46 3 230 kg. per ha. Stands were early spring sowings, and vernalized seed was used. But yields of 7 000—9 000 kg. per ha. are also reported (3, p. 5; 14), from stands grown on peats even 17 000 kg. of fresh roots per ha. (4, p. 35). The yields of rubber were not reported in connection with these figures. MYNBAEV (86) mentions that for some first year stands the yields of rubber varied from 70 kg. to 157.5 kg. per ha. in the years 1937—39.

According to NICHIPOROVICH (96) the rubber content of the roots of kok-saghyz is 1.5—2.0 % of the fresh weight in the first growing season, and 5.0—6.0 % in the second season. According to MANSKAYA and POPOV (71) the rubber content of the dry matter of the roots of unimproved kok-saghyz stands is usually 5.5—6.0 %. The rubber content of roots in some stands grown for experimental purposes was 5.0— 7.9 % (73, p. 309; 99, p. 313; 100). PROKOF'EV (114, p. 818) mentions in one of his investigations that the rubber content of the roots of second year stands was 11.6 % of dry matter, the corresponding figure for first year stands being 7.6 %. According to Russian investigations the rubber content of the dry matter of the roots may show considerable variations owing to cultural techniques. For instance, different fertilization and techniques of fertilization may considerably increase the rubber content of the dry matter of the roots, sometimes double it (4, pp. 83—84).

MYNBAEV'S (86) information indicates that the average yields of roots of kok-saghyz per ha. were rather low in U. S. S. R. in the years 1938—39. If rubber content is 2 % of the fresh weight of the roots in the first growth year, it means that the yield of rubber was in 1938 about 34 kg. per ha., and in 1939 about 40 kg. per ha. It is evident that owing to better cultural methods yields per ha. have increased after this. In some cases, for instance, when the yield of roots was 17 000 kg. per ha., it is probable that the yield of rubber was 300—400 kg. per ha. or even more, for the rubber content of the roots in first year stands may be higher than 2 % (4, p. 35; 92).

It is difficult to calculate the average yield of rubber for second year stands from the yield of fresh roots, for considerable changes occur in the rubber content during the second growing season, and thus the time of harvesting may have a decisive influence on the yield of rubber. According to MASHTAKOV (74, ref. 133, p. 124) the rubber content of the roots may in the second growing summer be double the rubber content in the first summer, at the most.

NOVIKOV (102) and IGNAT'EV (47) have studied the methods employed in extracting the usable substances of kok-saghyz roots (rubber, resin, and inulin) from the root material. KIUPT (55) has investigated the extraction of rubber by means of decomposing processes caused by microorganisms. NAVASHIN and CHEREDNICHENKO (91) have developed a simple field method for the determination of the rubber content of fresh roots, which is especially suitable for breeding work.

The investigations conducted in U. S. S. R. have proved that kok-saghyz rubber is of the same high quality as hevea rubber (19).

PAILLARD (104, p. 328) estimated that in 1946 the production of natural rubber in U. S. S. R. was some thousands of long tons. Kok-saghyz rubber probably occupied the first place, as kok-saghyz is usually mentioned first in the lists of rubber-bearing plants grown in U. S. S. R. But the amount of kok-saghyz rubber produced must be considered rather low as compared to the need for rubber in the whole country, which in 1946 was estimated at 180 000 long tons (104, p. 328).

When the Baltic countries were attached to U. S. S. R., cultivation of kok-saghyz was started in these areas. In 1941 kok-saghyz plantings covered about 1 000 hectares in *Latvia* (142, p. 3). The cultivation of kok-saghyz, which was interrupted by the war in the Baltic countries, has begun again after an interval of seven years.

According to the available information it was intended to grow kok-saghyz in *Lithuania* in 1948 on collective and private farms in 18 districts (157).

Germany.

In the years 1940—42 the Germans became familiar with the cultivation of kok-saghyz in the occupied territories, and they began to continue it (42). At the same time extensive investigations were started in Germany. They were mainly directed towards the breeding of the plant. At the head of this activity was at first *Unger*. In 1943 the lead was transferred to *Himmler* personally, mainly in order to secure the necessary labour for kok-saghyz plantings (31, p. 1).

During the first years of their investigations the Germans found that weather conditions, supply of nutrients, and management of plantings had a decisive influence on the yield of roots. By 1943 the yield of fresh roots had varied from 3 000 to 7 000 kg. per ha. The yield of rubber was in the first year of the experiments 60 kg. per ha (142, pp. 10—11; 31, p. 2). In 1944 the area of kok-saghyz plantings was 40 000 hectares, mainly in the occupied territories. The average yield of rubber from first year stands was 100 kg. per ha. (143).

After Germany's defeat there was a reaction in the cultivation of kok-saghyz. The German kok-saghyz experts maintained, however, that breeding of the plant and improvement of cultural techniques can develop kok-saghyz into a plant of temperate climate able to compete successfully with the rubber of the tropics even at peace time (31, pp. 3—4).

Sweden and some other European countries.

On the initiative of »Forskningens Beredskapsorganisation» and Swedish »Industrie Förbund» a conference was held towards the end of 1941 in **Sweden.** This conference made a decision to experiment with the production of native rubber. The experiments were started in 1942. At the Institute of Plant Husbandry of the Royal Agricultural College of Sweden cultivation tests with many rubber-bearing plants were carried out under the leadership of *Oswald.* These preliminary experiments showed that only kok-saghyz *(Taraxacum kok-saghyz)* possessed so high a rubber content as to justify further experiments. The seed used in Sweden in 1942 and 1943 was received from U. S. S. R. In 1944 seed was received from German kok-saghyz plantings in Poland.

At the beginning of 1943 F. B. O. transferred the investigations to »Statens Industriekommission», which, together with the Institute of Plant Husbandry of the Royal Agricultural College of Sweden took steps in order to start kok-saghyz plantings in Sweden. In the summer of 1943 *A. Ericsson* was sent by »Statens Industriekommission» to Germany and occupied territories to study the cultivation of kok-saghyz. In 1944 the experimental cultivations of kok-saghyz in different parts of the country were all transferred to »Statens Industriekommission». As it was considered necessary to give more attention to breeding and improvement of cultural methods, the parliament granted funds for these investigations in the same year. »Sveriges Utsädesförening» began to conduct these investigations. Svalöf was the centre of breeding work. Experiments with cultural operations, including fertilization, time of sowing, spacing of rows and seedlings, etc. were conducted at Flahult, because there was no peat soil at Svalöf, and peat is considered the best soil for kok-saghyz. »Industriekommission» has also continuously supported the investigations directed towards the mechanization of cultural operations (7, pp. 174—175; 6, p. 271).

The first experimental area at Ultuna in 1942 yielded 125 kg. of rubber per ha. (103). Andersson (6, p. 274) reports that the average yield from all kok-saghyz stands in Sweden in 1944 was 2 280 kg. of roots per ha. The rubber content of the roots was 1.9 % of the fresh weight. Average yield of rubber was 43 kg. per ha. The best stand in Halland yielded 4 020 kg. of fresh roots per ha. Their rubber content was 2.7 %, and the average yield of rubber per ha. 109 kg.

Cultivation tests at Flahult resulted in varied yields owing to cultural methods. The best crops were obtained from unthinned stands with rows spaced 25 cm. apart. The yield of roots was 6 500 kg. per ha., the rubber content of fresh roots 1.9 %, and the yield of rubber 124 kg. per ha. The result was one of the best obtained in Sweden by 1944. In

1944 also vegetative propagation was tested, but the results were negative (6, pp. 274—275).

In 1945 cultivation tests were carried out at 150 localities in different parts of the country on a total area of 10 ha. The northernmost plantings were in northern Norrland, and the southernmost in Skåne (148; 156). Yields were considerably lower than in 1944. The best experimental planting at Flahult yielded in 1945 only 63 kg. of rubber per ha. At Svalöf a stand established from seedlings only yielded 31 kg. of rubber per ha. (6, p. 275).

The production costs of kok-saghyz rubber were estimated at 20 Swedish crowns per ha., if the yield of rubber was 68 kg. per ha. Also the inulin, separated from roots, was taken into consideration. Its value was estimated at 9 Swedish crowns per 1 kg. of rubber. At the same time the price of the natural rubber of the tropics was 2.25 Swedish crowns per kg. (6, p. 276).

The quality of kok-saghyz rubber was also investigated in Sweden, and it was found to be equal to hevea rubber. Kok-saghyz rubber was used, for instance, for the preparation of the rubber parts in milking machines (148).

The state and the rubber factories of Sweden have granted funds to the investigations of kok-saghyz, and these investigations have been continued in 1946—49 (127; 158, p. 339; 159, p. 140; 196; 160, pp. 148—149; 180).

Experiments with kok-saghyz were started also in many other countries of Europe at the beginning of 1940's. Hungarian NADAS (89, pp. 61, 86) reports that kok-saghyz was grown in 1942 in **Hungary, Roumania,** and **Bulgaria.** In his opinion the cultivation of kok-saghyz was inadvisable in Hungary owing to great expenditure of labour.

The first information concerning the cultivation of kok-saghyz in **France** was published in 1943. The rubber content of the dry matter of roots varied from 3 to 11 % (153). CHEVALIER (26) and BALLEREAU (10) have also studied the question of growing kok-saghyz in France. The former finds kok-saghyz an unsuitable plant for France, because it requires large areas owing to low yields per ha. BALLEREAU published an investigation on rubber-bearing plants thriving in France, in 1946. In his opinion kok-saghyz is a plant with great possibilities of developing into a crop plant.

Experiments for finding a native rubber-bearing plant have also been conducted in **Spain.** FERNANDEZ, NUNEZ, and IZQUIERDO (33—35) have paid special attention to some problems related to plant breeding and extraction of rubber from roots.

In **England** investigations on kok-saghyz were started in 1943 when the first experimental cultivations were established at 20 different localities in different parts of England. Seed was received from U. S. S. R. At the same time experiments on krim-saghyz and tau-saghyz were carried out. Kok-saghyz was considered better than the other two species (45).

In **Finland** investigations of the possibilities of growing kok-saghyz were begun in the spring of 1943 on the initiative of OTTO VALLE, head of the Department of Plant Husbandry of Agricultural Research Institute, Tikkurila. He wrote the first instructions and published the first data on kok-saghyz in Finland (129; 130).

America.

Before the war natural rubber was the chief import of U. S. A., and she consumed more than one half of the rubber production of the world. As the quality of synthetic rubber was not equal to that of natural rubber, the long war time initiated extensive investigations which were directed towards the possibilities of producing natural rubber in America. In the tropical parts of America: South America, Bolivia, and Brasilia extensive experiments on species of *Hevea* were started in 1940.

In the subtropical parts investigations were started on *Parthenium argentatum* (guayule) and *Cryptostegia grandiflora* (rubber-bearing shrub) (134). In the temperate regions of America species of *Solidago* (goldenrod) were investigated at first, but when America in 1942 received 500 kg. of kok-saghyz seed from U. S. S. R., extensive investigations of this plant were started. Experimental areas were located in different parts of America, mainly in **U. S. A.** and **Canada.** Hardly any plant has been so thoroughly investigated in America in a short time as kok-saghyz (24, p. 492, 494). On the largest scale these investigations were conducted in U. S. A. Some of the institutions taking part in this work may be mentioned here: United States Department of Agriculture, the Bureau of Plant Industry, Forest Service, the Bureau of Entomology and Plant Quarantine, and Bureau of Agricultural and Industrial Chemistry (133, pp. 7—8).

Besides cultural techniques (72; 79; 80—81; 133) also problems related to the anatomy and the biology of kok-saghyz were investigated (9; 40; 64; 123). WHALEY and BOWEN (133) report in the publication from 1947 the results obtained in the experiments conducted in U. S. A. in 1942—44.

In the experiments of 1943 the yield of fresh roots from first year stands varied from 220 to 10 000 kg. per ha. The rubber content of the roots averaged 4—5 % for air-dry roots (133, pp. 143, 144, 172). The experiments conducted in Europe have resulted in approximately the same rubber content.

No estimations were published for the average yields from second year stands. It is evident that kok-saghyz was mainly grown as an annual. ZEHNGRAFF and AAMODT (139, ref. 133, p. 142) estimated that the yield of rubber from a second year stand in Minnesota varied from 84 to 123 kg. per ha. The roots were harvested in the middle of the summer.

The test plantings in Canada produced rather high yields of roots. In 1943 the average yield of roots from first year stands was 5 800 kg. per ha. One experimental planting yielded 10 700 kg. of fresh roots per ha. (149).

Also the extraction of rubber from the root by means of different methods and the quality of kok-saghyz rubber were investigated in U. S.A. (32; 133, p. 145).

The investigations in the years 1942—44 showed that natural rubber of high quality could be produced in U. S. A. by growing kok-saghyz. When unimproved seed was used the costs of production were, however, so high that the cultivation of kok-saghyz could be recommended only when a serious shortage of hevea rubber occurred.

Whether kok-saghyz has possibilities to develop into a real crop or not, depends upon improvement in its vigour, size, and rubber content (133, p. 181). American investigators think that such improvement could be made in 8 to 10 years with little difficulty. WARMKE (131; 132) may be mentioned among the investigators who have worked on the breeding of koksaghyz. He obtained favourable results with tetraploid kok-saghyz plants.

The breeding of kok-saghyz, as well as biological problems and cultural methods have received special attention in Canada (11; 12; 149—152).

In America kok-saghyz is commonly regarded as a useful object of study, for investigations of this herbaceous, quickly developing plant may add to our knowledge concerning the synthesis of rubber and its function in plants, and at the same time kok-saghyz plant itself is improved as a source of rubber (133, p. 181—183).

Australia.

Kok-saghyz has also been tested in Australia and New Zealand. The experiments were started in 1942. In addition to kok-saghyz the same rubber-bearing plants as in America were investigated. The experiments showed that production of rubber from these plants was for the present economically inadvisable, but the results were so promising as to justify further experiments (27; 140).

II. Survey of the biology of kok-saghyz.

Kok-saghyz belongs to the Compositae family, and is a perennial, herbaceous plant which morphologically resembles the common dandelion *(Taraxacum officinale)*. Its flower scapes, 15—20 cm. long, are slenderer and more numerous, and its flowerheads paler in colour and smaller than those of the common dandelion. Flowerheads are characterized by bracts with hornlike appendages.

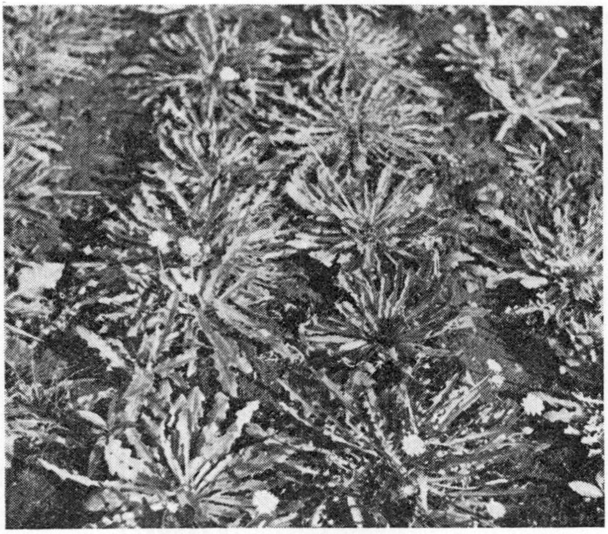


Figure 1. First year kok-saghyz stand at Mouhijärvi Sept. 10 1943. Photograph by O. Valle.

The rosette of leaves is decumbent and consists of 20—50 leaves, 10—15 cm. long and 1—2 cm. wide at the widest part. The margins are turned downwards. The leaf form varies considerably in that some leaves have entire, some sharply incised margins (Figures 1 and 2). The surface of the leaves is glossy and their colouring bluish green (9, p. 3; 59; 119).

Figure 2. Second year kok-saghyz stand at Tikkurila July 7 1944. Photograph by O. Valle.

Root forms also show much variation due to environmental factors, but the most typical form is a straight, deep-penetrating taproot with some branches (Fig. 3). The length of the root is generally 20—40 cm. and its diameter at the crown 1—1.5 cm. According to RUDENSKAYA (121), under favourable conditions the root may attain a thickness of 3.5 cm. at the crown, if the plants are spaced far apart.

The weight of the roots of wild plants is 3—5 g. (147, p. 28). The size of the root is naturally dependent on growth space and supply of nutrients. When the plant is cultivated and stands are thin, the weight of the roots may be 20—30 g. per piece. Some roots may attain the weight of 100 g. or even more, if the plant is vegetatively propagated from root cuttings (31, p. 23, 69).

A fully developed kok-saghyz root consists of a small woody core and a broad band of secondary phloem in which tissues of parenchyma alternate with concentric rings of phloem. The secondary phloem consists of sieve tubes, companion cells, phloem parenchyma, and latex tubes (9, p. 13). Rubber is formed and accumulated in the latex tubes of the secondary phloem, where it appears as coagulated in small balls. Some rubber is found in the root of kok-saghyz already on the first day after germination (16; 17; 114; 115; 117).

Kok-saghyz is a cross-pollinated plant, and its seeds develop sexually. The plant does not cross with parthenogenetic species of *Taraxacum*, including *Taraxacum officinale* and most other species of *Taraxacum*.

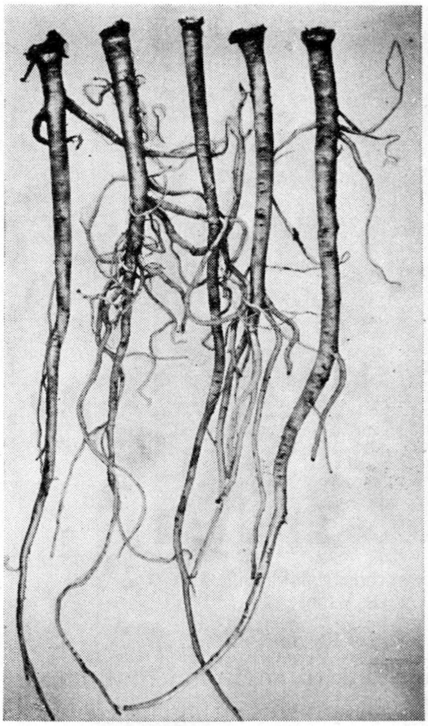


Figure 3. Typical kok-saghyz roots of first year plants at Vihti Oct. 6 1943 ($^1/_3$ natural size). (Orig.)

Sexual species of *Taraxacum*, such as kok-saghyz are generally diploids (16 chromosomes), while parthenogenetic species are polyploids (108, p. 374; 109, p. 383). Bees belonging to *Halictus* family were found to carry out the pollination under natural conditions in U. S. S. R. Common bees carried pollen only under greenhouse conditions. On the other hand, in U. S. A. it is thought that bees play an important part in the pollination of kok-saghyz also under field conditions (133, p. 104). Pollination may also be done by some species of flies visiting the flowerheads (39). WARMKE (131) reports self-fertilization in kok-saghyz late in autumn under favourable conditions, but not apomixis.

The seed of kok-saghyz germinates and sprouts slowly and unevenly, which is generally typical of the seeds of wild, unimproved plants. The rosette of leaves remains small for nearly 2 months, during which time the main development of the roots takes place (5, p. 52). Leaves begin to grow after this. This period is characterized by high assimilation. The plants require plenty of nitrogen for the protein synthesis in the leaves. When the protein synthesis is over, the accumulation of carbohydrates and rubber begins (99, p. 313).

Under wild conditions kok-saghyz does not flower until the second growing season (9, p. 3). When the plant is cultivated, however, the first flowerheads appear 60 to 70 days after sowing, if conditions are favourable (133, p. 17). Generally plants with widely different dates of flowering have been found in unimproved stands. 20—30 % of the plants flower in the first growing season, part early in the summer and the other part late, so that the period of flowering is prolonged (60). Under the most favourable conditions the proportion of flowering plants in a stand may be 80—90 % (78, p. 264). The seed matures quickly after flowering, and it is dispersed by wind like the seed of the common dandelion. The seeds of kok-saghyz resemble those of the common dandelion, except that they are a little smaller in size, the weight per 1 000 seed being, according to KOROLEVA, 0.4—0.8 g. (59, p. 31).

Kok-saghyz is characterized by a dormant period after flowering. During this stage all the above-ground parts of the plant wilt. Unfavourable conditions and drought hasten dormancy, which lasts for 30—45 days. After dormancy the plant develops new rosettes in autumn and winters at this stage. In order to go through both of these stages in the first growing season the plant requires a growth period of 7 months (123, p. 31).

Kok-saghyz endures low temperatures. Even young seedlings resist the temperature of —4° C. The roots of the plants are susceptible to frost heaving and to the attacks of decomposing organisms (141, p. 5; 133, p. 32—33).

After winter kok-saghyz begins to develop new rings of cambium in the following summer. New cortical tissue with latex tubes is then formed, which causes an increase in the rubber content of the root (113). After flowering the old cortical tissue is sloughed off. When the tissues disintegrate, the rubber-containing latex coagulates, and for some time a netlike texture of rubber is left on the surface of the new cortical tissue (3, pp. 11—12). When the new cortical tissue is formed after flowering the plant enters dormancy, 1 or 2 months earlier than first year plants (123, p. 31).

The chemical structure of the root varies due to growth conditions, individual plant, and age of root. According to IGNAT'EV (47) the dry matter of the first year roots contains the following average proportions of technically usable substances:

rubber	6— 8 %
resins	3— 4 »
inulin (carbohydrates)	38—41 »

The rubber content of the roots is about doubled towards the middle of the second summer before the old cortical tissue is sloughed off (73; 74). Dry matter content in fresh roots ranges from 20 to 30 % (47).

In unimproved kok-saghyz stands there are individual plants, the rubber content of which may be over 15 %, up to 25 %, based on the dry matter of the roots. In Canada 160 plants out of 3 500 examined plants contained more than 15 % rubber in the dry matter of the roots (152). At the improvement of kok-saghyz stands individual selection can be based upon the rubber content of the roots. It can also be based upon the size of the root. In branched, shrublike roots rubber content is usually higher than in branchless taproots (34; 36). There are, however, individual plants with thick taproots having several rings of cambium in the cortical tissue. Their rubber content is higher than that of ordinary taproots. Vegetative propagation of such plants resulted in plants with larger root size and higher rubber content as permanent plant characteristics (71).

Many investigations have shown, in addition, that with regard to rubber production plants which do not flower during their first growing season are superior to flowering plants, for on the average they develop larger roots than flowering plants (62; 78; 93).

There are many assumptions as to the importance of latex tubes and rubber to the plant. It has been suggested that the coagulating latex is a protective substance forming a protective layer on the surface of damaged tissues. NICHIPOROVICH (98) explains that to some extent latex tubes regulate the water supply of the plant. It is also claimed that rubber must not be considered a waste product; it has some close relation to the vital functions of the plant (105, p. 302). PROKOF'EV (115) again regards rubber and resins in the roots as byproducts of metabolism. The assumptions as to the importance of rubber to the plant differ widely, and for the present this question must be considered unsolved.

III. Investigations in Finland in the years 1943—1948.

1. Purpose and materials of investigations.

The purpose of the investigations has been to illustrate the possibilities of growing kok-saghyz *(Taraxacum kok-saghyz)* in Finland, and to find suitable cultural methods for this country. Special attention was paid to the development of the plant under Finnish conditions, to the yields of roots and rubber, and to the most important cultural methods affecting the yields.

Investigations were mainly based on cultivation tests with kok-saghyz carried out at Tikkurila, at Agricultural Research Institute, Department of Plant Husbandry. The experiments consisted of field tests and laboratory experiments concerning the germination, vernalization, and emergence of kok-saghyz seeds. In the field tests of 1943—47 kok-saghyz seed was usually sown in single rows in the field. Also planting of seedlings and vegetative propagation were tested. Field trials were carried out in order to find out the effect of vernalization, date of sowing, and date of harvesting on the yields. In connection with the dates of harvesting experiments also changes in the dry matter and rubber contents of roots during the different stages of development in first and second year plants were observed.

Investigations were also partly based on experimental plantings (1—10 ares), which were established in different parts of Finland in 1943—47. The number of these plantings varied yearly from 17 to 49 (Table 1).

Table 1 shows the total number of experimental fields in different years. Fields are grouped in the following way: successful plantings, plantings failed for inadequate cultural methods, and plantings failed for other reasons. A planting which yielded 1 000 kg. of roots or more per ha. in the first or second growing season was considered successful. Too deep sowing and too late weeding were the most usual cultural operations resulting in failure of plantings.

Analysis of all root samples was conducted at Agricultural Research Institute, Department of Plant Husbandry, Tikkurila. The dry matter content of fresh roots, and the rubber and resin contents of the

Table 1. *Experimental fields of kok-saghyz in 1943—1947.*

Year	Number of experimental fields.	Successful plantings	Failures	
			due to cultural methods	due to other reasons
1943—44	49	24	14	11
1944—45	40	28	8	4
1945—46	17	11	5	1
1946—47	20	18	1	1

dry matter were determined on the samples. The rubber content of fresh roots was calculated from these. Rubber and dry matter contents were determined quantitatively by extracting air-dry, ground root mass with benzene. Rubber was separated from resin by extracting it with acetone. This method is commonly employed at the determination of the rubber content of plant tissues (31, p. 43; 136).

The determinations of rubber and resin contents were made by Miss Elli Auterinen, graduate in engineering, in 1943—44, and by the author in 1945—47.

The analysis of variance method was used in testing the significance of the most important results (20, pp. 34—42; 106, pp. 344—357; 146, pp. 142—158). Variance ratio (F), minimum significant difference and the proportion of standard error in the mean yield (m %) are reported for each test.

The significance of variance ratio is given with indices *, **, ***, which mean:

* probability has a value between 95/100 and 99/100,
** probability has a value between 99/100 and 999/1 000,
*** probability is greater than 999/1 000.

In testing the significance the table values of F and t[1]), according to Bonnier-Tedin (20, pp. 318—321), were used.

2. General aspects.

a. *Geographical locality and climatic conditions of experimental fields.*

The whole of Finland is situated within the area of humid and cold winter climate, and the country is characterized by long winters and

[1]) Ratio of a range in a statistical measure in terms of that measure's standard error.

short summers. Precipitation is distributed throughout the year (8, p. 127). The climatic conditions in the native habitat of kok-saghyz are in the main similar to Finnish climatic conditions, except that the climate in Finland is more favourable with regard to the length of growing period and precipitation due to cyclonie activity and prevailing winds from ocean. With regard to the temperature Finland must also be considered suitable for the development of kok-saghyz, for it is a plant of the temperate zone, and high temperatures have injurious effects on its development and on rubber formation (cp. 22; p. 107; 63; 112, p. 43; 133, p. 31; 149).

In the native habitat of kok-saghyz, in the Tien Shan Mountains at 1 800—2 000 m. above sea level the length of the growing season is the same as in northern Finland, 130—135 days. The maximum temperature in summer days may be higher than 50° C, but night frosts are usual. Cucumber cannot be grown in these regions, and even the cultivation of potato is uncertain. Subsoil is frozen all through the summer and the temperature of the top layers of the soil seldom exceeds 15° C. Precipitation during the growing period is only about 150—180 mm. (31, pp. 14—18; 120).

Tikkurila where the most extensive cultivation tests with kok-saghyz were conducted is situated in the south of Finland, near the Gulf of Finland so that the sea has a considerable influence on the climate. The geographical locality of Tikkurila is 60° 17′ N. L. 25° 04′ E. L. The length of the growing season is about 170 days, beginning in the first week of May and ending towards October 20 (53, pp. 139—141).

The growing seasons (May—September) of the years 1943—47 were at Tikkurila a little warmer than normal (Table 2). Precipitation was high in 1943 and 1944 (420—430 mm.), in 1945 and 1946 precipitation was about normal (333 mm.), whereas the precipitation of the growing season in 1947 was exceptionally low (220 mm.) (Table 3).

The winters 1943—44 and 1944—45 were mild, the average temperature for October—April being ± 0° C. The average temperatures of the following winters (October—April) were about normal (—2.3° C) (Table 2).

With regard to snow conditions the first three winters were normal. The ground was covered with snow for 4—4.5 months and the thickest snow cover in March was 40—50 cm. The snow conditions of 1946—47 were exceptional. The ground was covered with snow only for 98 days, and snow cover was thin throughout the winter (Table 4).

Great differences occurred in different years with regard to freezing of soil. The two first winters must be considered mild in this respect, whereas in the winter 1946—47 the soil was deeply frozen (92 cm.) owing to thin snow cover (Tables 4 and 5).

Table 2. Average temperatures and deviations from normal values in the years 1943—1947 at Tikkurila.

	Month	Normal C°	1943		1944		1945		1946		1947	
			Average temperature	Deviation from normal	Average temperature	Deviation from normal	Average temperature	Deviation from normal	Average temperature	Deviation from normal	Average temperature	Deviation from normal
	January	—5.9	—7.6	—1.7	—3.0	+2.9	—5.1	+0.8	—4.1	+1.8	—7.9	—2.0
	February	—6.5	—0.3	+6.2	—4.4	+2.1	—3.7	+2.8	—8.6	—2.1	—14.8	—8.3
	March	—3.6	—0.3	+3.3	—3.0	+0.6	—3.7	—0.1	—4.7	—1.1	—7.8	—4.2
	April	2.1	4.8	+2.7	0.5	—1.6	3.4	+1.3	3.8	—1.7	2.8	+0.7
Growing season	May	8.6	10.0	+1.4	7.9	—0.7	7.9	—0.7	9.2	+0.6	10.6	+2.0
	June	13.1	15.5	+2.4	12.6	—0.5	13.5	+0.4	15.1	+2.0	16.0	+2.9
	July	16.3	16.0	—0.3	17.5	+1.2	18.6	+2.3	18.9	+2.6	17.2	+0.9
	August	14.0	14.7	+0.7	16.3	+2.3	16.6	+2.6	15.1	+1.1	16.1	+2.1
	September	9.7	10.7	+1.0	10.8	+1.1	8.8	—0.9	11.9	+2.2	11.4	+1.7
	October	4.5	7.9	+3.4	7.0	+2.5	2.8	—1.7	2.1	—2.4	3.3	—1.2
	November	—0.2	2.4	+2.6	1.3	+1.5	—0.1	+0.1	0.7	+0.9	—0.6	—0.4
	December	—4.2	0.1	+4.3	0.0	+4.2	—7.3	—3.1	—1.3	+2.9	—3.9	+0.3
	Year	3.0	6.2	+3.2	5.3	+2.3	4.3	+1.3	4.8	+1.8	3.5	+0.5
	Growing season	12.3	13.4	+1.1	13.0	+0.7	13.1	+0.8	14.0	+1.7	14.3	+2.0

Table 3. Precipitation in different months of 1943—1947 and deviations from normal values at Tikkurila.

	Month	Normal [1] mm.	1943		1944		1945		1946		1947	
			Precipitation	Deviation from normal	Precipitation mm.	Deviation from normal	Precipitation mm.	Deviation from normal	Precipitation mm.	Deviation from normal	Precipitation mm.	Deviation from normal
	January	50	23	—27	53	+3	63	+13	24	—26	25	—25
	February	37	44	+7	11	—26	35	—2	33	—4	17	—20
	March	41	26	—15	27	—14	26	—15	29	—12	6	—35
	April	42	39	—3	49	+7	36	—6	36	—6	21	—21
Growing season	May	47	44	—3	82	+35	35	—12	59	+12	33	—14
	June	53	84	+31	110	+57	59	+6	64	+11	39	—14
	July	70	129	+59	84	+14	92	+22	26	—44	126	+56
	August	88	115	+27	51	—37	109	+21	36	—52	3	—85
	September	75	60	—15	94	+19	23	—52	151	+76	19	—56
	October	79	74	— 5	76	— 3	83	+ 4	17	—62	32	—47
	November	69	114	+45	128	+59	21	—48	49	—20	43	—26
	December	57	30	—27	65	+ 8	45	—12	24	—33	76	+19
	Year	708	782	+74	830	+122	627	—81	548	—160	440	—268
	Growing season	333	432	+99	421	+88	318	—15	336	+ 3	220	—113

[1]) According to KORHONEN (58).

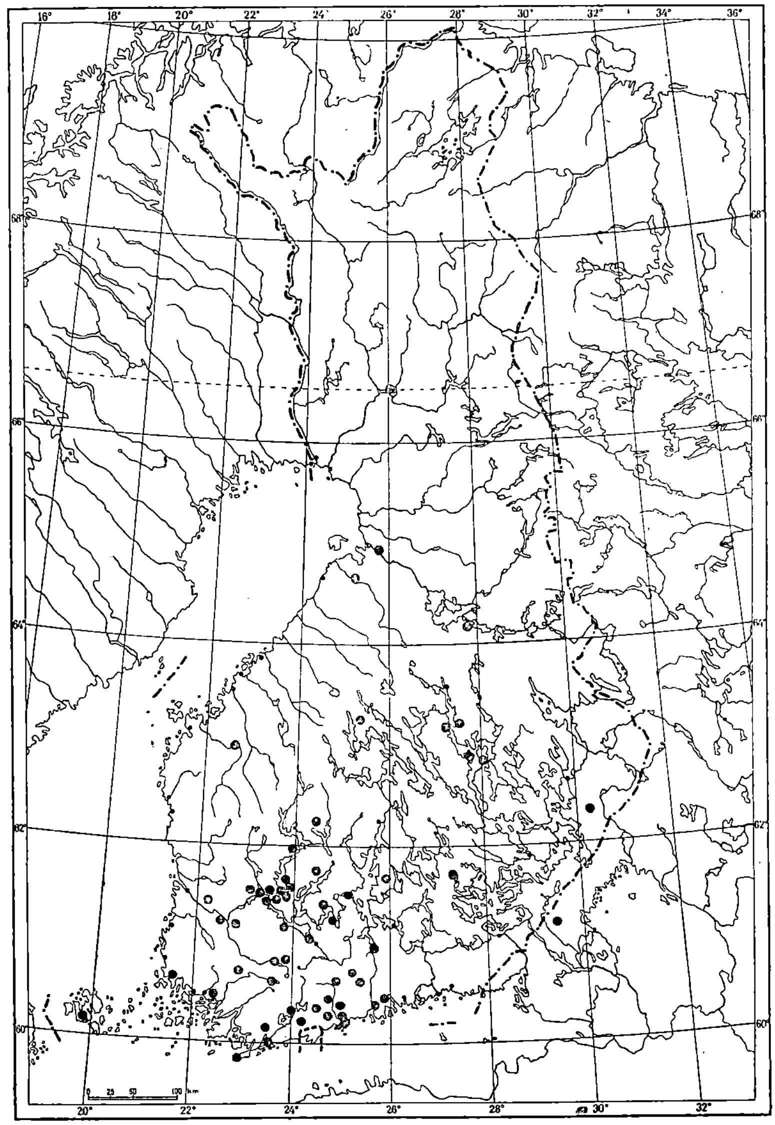
Table 4. Snow conditions at Tikkurila in the years 1943—1947.

Month	Normal snow cover on the 15th of the month cm.	1943—44			1944—45			1945—46			1946—47		
		Number of days with snow cover	Snow cover cm.		Number of days with snow cover	Snow cover cm.		Number of days with snow cover	Snov cover cm.		Number of days with snow cover	Snow cover cm.	
			aver-age	on the 15th		aver-age	on the 15th		aver-age	on the 15th		aver-age	on the 15th
October	—	—	—	—	—	—	—	—	—	—	3	6	8
November ..	2	8	4	—	8	4	2	11	6	6	—	—	—
December ..	11	20	4	3	19	6	—	31	11	10	5	4	—
January	23	28	12	16	27	19	8	31	26	24	24	8	22
February ...	39	29	24	26	28	41	39	28	39	42	28	8	5
March	48	31	38	37	31	48	51	31	49	49	31	19	18
April	15	20	32	30	8	20	—	14	19	6	7	8	—
Total		136			121			146			98		

Table 5. Observations on frost in the soil.

Winter	Date of observation	Frost in the ground cm.	Snow cover cm.	Soil frozen	Soil thawed
1943—44	April 1	20	35	January 3	April 28
1944—45	March 1	14	48	December 18	» 12
1945—46	»	38	55	» 15	May 3
1946—47	»	92	19	October 15	» 15

Experimental fields used as material for investigations in addition to the field at Tikkurila were mainly located between 60th and 62nd degrees of N. L. in the southern and south-western parts of Finland (Map 1 and Table 6), only a few of the fields were located outside this region. The length of growing season varies in southern and south-western Finland from 155 to 180 days, beginning in May and ending in September or October (53, pp. 139—141). In the inner parts of the country with more continental climate the growing season begins a little later and ends a little ealier than on the coast. On the northernmost locality at Apukka, 66° 35′ N. L. 26° 00′ E. L., the length of the growing season is only 130 days.



Map 1. Experiment localities of kok-saghyz in Finland in the years 1943—1947.

In 1943—47 the weather conditions in southern and south-western Finland were in the main similar to those at Tikkurila (see pp. 24—25). The deviations of average temperatures and precipitations from normal at different localities during the growing season are given in Table 7. Snow cover and frost in the soil in experimental fields in 1943—47 are given in Table 8.

Table 6. Geographical co-ordinates of the most important experiment localities.

	Latitude N.	Longitude E.		Latitude N.	Longitude E.
Apukka	66°35′	26°00′	Mouhijärvi	61°31′	22°59′
Fiskars	60°68′	23°32′	Nokia	61°28′	23°30′
Hanko	59°49′	22°58′	Porvoo	60°24′	25°41′
Hartola	61°35′	26°00′	Peipohja	61°17′	22°14′
Jomala	60°06′	19°56′	Pälkäne	61°20′	24°13′
Kangasala	61°28′	24°05′	Revonlahti, Ruukki	64°41′	25°04′
Karjalohja	60°14′	23°41′	Savio	60°23′	25°07′
Lahti	60°58′	25°39′	Siilinjärvi	63°09′	27°19′
Hattula, Leteensuo	61°04′	24°15′	Tammisto	60°17′	24°58′
Maaninka	63°09′	27°19′	Vihti	60°21′	24°31′
Mikkeli	61°40′	27°13′	Ylistaro	62°57′	20°30′

The different weather conditions of the years 1943—47 were partly harmful, partly favourable to the investigations. As a considerable advantage may be mentioned that it was possible to find out the effects of different temperatures and precipitations on the development of kok-saghyz, which was now cultivated in Finland for the first time.

Table 7. Deviations of average temperatures and precipitations from normal values at the most important experiment localities during the growing seasons 1943—1947.

Locality	Temperature						Precipitation					
	May—September						May—September					
	Normal C°	Deviation from normal					Normal mm.	Deviation from normal				
		1943	1944	1945	1946	1947		1943	1944	1945	1946	1947
Apukka	9.9	+1.4	—	—	—	—	275	+ 23	—	—	—	—
Jomala [1])	11.9	+1.0	+1.0	+1.1	+1.2	+2.1	248	+ 60	— 37	+68	+ 2	—109
Lahti	12.1	+0.6	+0.7	+0.5	+1.1	+1.0	338	+209	+ 55	— 5	—14	—185
Leteensuo	12.1	+0.8	+0.3	+0.6	+1.1	+1.9	307	+ 98	+103	+39	+ 7	—159
Maaninka	11.7	+0.9	+0.1	+0.6	+1.3	+1.8	299	+ 75	— 57	—81	+67	— 97
Mikkeli	11.8	+1.0	+0.5	+0.6	+1.1	+1.3	325	+116	+ 62	—32	+57	—119
Mouhijärvi	11.8	+0.8	+0.3	+0.7	+1.2	+1.7	323	+101	— 18	—13	+ 2	—161
Nokia [2])	12.6	+0.1	—0.2	±0	+0.5	+1.7	326	+ 59	+ 74	+46	—12	—176
Pälkäne	12.1	+0.9	+0.5	+0.7	+1.2	+1.8	310	+103	+ 59	+25	+ 5	—131
Ruukki	10.8	+1.1	+0.3	+1.1	+1.2	+2.3	294	+ 17	— 90	—28	—28	—228
Vihti	11.9	+0.8	+0.5	+0.8	+1.2	+2.5	331	+108	+ 92	+23	+82	—134
Ylistaro	11.6	+1.2	+0.5	+1.0	+1.3	+2.4	320	— 40	+ 19	—86	—15	—250

[1]) Values from the nearest climatic station at Marianhamina.
[2]) Values from the nearest climatic station at Tampere.

Table 8. Snow and frost conditions in the soil in experimental fields in the years 1943—1947.

	Number of days with snow cover				Deepest snow cover (cm.)				Frost in the soil cm.				Date of thawing			
	1943—44	1944—45	1945—46	1946—47	1943—44	1944—45	1945—46	1946—47	1943—44	1944—45	1945—46	1946—47	1943—44	1944—45	1945—46	1946—47
Apukka ..	137	—	—	—	80	—	—	—	35	—	—	—	May 16	—	—	—
Fiskars ..	88	—	122	103	40	—	50	40	20	—	25	90	» 1	—	April 20	XX
Hanko ...	—	—	153	67	—	—	40	25	—	—	40	80	—	—	» 25	XX
Hartola ..	121	113	—	—	60	70	—	—	30	30	—	—	May 10	May 1	—	—
Jomala ..	30	—	—	93	15	—	—	20	X	—	—	80	—	—	—	XX
Kangasala	120	140	—	105	40	60	50	20	40	—	30	120	May 10	May 15	May 5	XX
Lahti	—	171	—	63	—	60	—	40	—	15	—	80	—	April 22	—	XX
Leteensuo	179	134	—	69	30	40	—	15	24	—	—	60	May 9	—	—	XX
Maaninka.	135	161	—	122	40	70	60	40	40	5	60	50	» 17	April 30	May 9	XX
Mikkeli ..	—	—	157	126	—	—	60	40	—	—	35	40	—	—	» 4	—
Mouhijärvi	192	93	—	85	55	40	—	15	X	—	—	90	—	—	—	XX
Nokia ...	119	139	111	70	50	60	60	20	40	30	30	50	April 30	April 28	April 15	XX
Porvoo ..	—	109	—	—	40	70	—	—	10	10	—	—	May 5	» 15	—	—
Pälkäne ..	—	98	—	106	—	55	—	20	—	20	—	100	—	» 20	—	XX
Ruukki ..	125	114	146	103	30	30	40	30	10	45	90	90	May 10	June 5	May 15	XX
Savio	130	95	98	122	40	55	50	50	20	15	40	75	» 5	April 23	April 25	XX
Tammisto.	109	—	—	—	40	—	—	—	30	—	—	—	» 1	—	—	—
Vihti	—	133	—	122	—	45	—	30	—	15	—	70	—	April 13	—	XX
Ylistaro ..	89	—	116	100	30	—	35	30	50	—	60	65	May 25	—	May 7	XX

X = frozen layer thin, exact measurings were not made.
XX = subsoil frozen as late as May 15.

b. *Establishment and management of field tests and experimental fields.*

Soil, previous crop, ground preparation and fertilization.

When the experimental areas for kok-saghyz plantings were selected and prepared, advantage was taken of the results achieved in other countries, especially in U. S. S. R.

The field tests with kok-saghyz at Tikkurila, Agricultural Research Institute, Department of Plant Husbandry were carried out on low sand soil with high organic content. Only small areas were located on clay soil. No suitable peat soil for the cultivation of kok-saghyz was available. Test soils had a pH range from 5.8 to 6.4.

In its native habitat kok-saghyz thrives best on very wet meadows where water table is close to the surface. Soil is rich in humus, mixture of clay and sand, and granular in structure. Soil reaction is alkaline though the subsoil water is acid (31, p. 18; 112, p. 43).

Kok-saghyz was most commonly grown after beets and potato (Table 9). At some localities experimental fields were also established after third or fourth year's grass. Most of these plantings failed. The chief reason was evidently inadequate seedbed preparation, for kok-saghyz requires well-prepared soil for satisfactory emergence.

ALTUKHOV (3, pp. 13—14) recommends that kok-saghyz should be grown in crop rotation after plants which have received plenty of fertilizers and which prevent growth of weeds. The best method in his opinion, however, is to grow kok-saghyz in a fallowed and well manured field. POLOVENKO (112, pp. 51—50) recommends the cultivation of kok-saghyz on peat soils after some autumn or spring crop.

According to the investigations conducted in U. S. S. R., kok-saghyz takes from the soil yearly 25—30 kg. of P_2O_5, 110—120 kg. of K_2O, and 40—60 kg. of N per ha. In the Black Earth areas in U. S. S. R. fertilizers should be applied at the following rate per ha.: 170 kg. of P_20_5, 60 kg. of K_2O, and 90 kg. of N (3, p. 22—23). The Germans thought that application of such large amounts of nutrients to wide plantings was difficult and uneconomic during the war. Therefore they recommend considerably smaller amounts of fertilizers; for fresh mineral soils, for instance, only 40 kg. of P_2O_5 and for dry mineral soils 80 kg. of K_2O per ha. (141, p. 9).

The experimental areas were usually manured with dung in autumn in connection with ploughing (40 tons per ha.). In spring fertilizers were applied at the following rate per ha.: 50 kg. of P_2O_5, 60—120 kg. of K_2O, and 30 kg. of N. Besides, 30 kg. of P_2O_5, 40 kg. of K_2O, and 20 kg. of N per ha. were applied as supplemental fertilization. After emergence of plants 30 kg. of N was applied per hectare. 30 kg. of P_2O_5, 40 kg. of K_2O, and 20 kg. of N, and a second application of 30 kg. of N were applied in spring to kok-saghyz stands carried over through the winter.

The same instructions as at Tikkurila were observed in experimental fields in different parts of Finland. The soil, reaction, previous crop, and fertilization in these fields are summarized in Table 9. Generally it was attempted to establish experimental fields on cultivated mineral soils with high organic content. As Table 9 shows, most of the experimental fields were located on sand and finesand soils. It is easy to prepare sand soils with high organic content so that even seedbed necessary for satisfactory emergence of kok-saghyz is attained. The drawback of sand and finesand soils is that heavy rains cause a compaction of the surface of the soil so that seeds are buried too deep, which delays emergence. Plantings on heavy clay soil and silt clay soil with low organic content often fail for the same reason.

Only five experimental fields were located on peat soils. Three of these failed completely, evidently due to the low degree of huminication and the acidity of soil. At Vihti and Leteensuo plantings on peat soils were

Table 9. Soil characteristics, crop rotation, fertilization

Locality	Soil type and pH.				Previous crop			
	1943	1944	1945	1946	1943	1944	1945	1946
Apukka ..	Sand pH 6.2	—	—	—	Peas	—	—	—
Fiskars ...	Heavy clay pH 6.1	Heavy clay pH 6.1	Heavy clay pH 6.1	Heavy clay pH 6.1	Sugar beets	Sugar beets	Sugar beets	Sugar beets
Hanko ...	—	Sand	Sand	Sand	—	Potatoes	Potatoes	Potatoes
Hartola ..	Finesand pH 6.6	Finesand	—	Finesand	Carrots	Carrots	—	Carrots
Jomala ...	Heavy clay	Heavy clay	—	Finesand clay	Potatoes	Sugar beets	—	Cucumber
Kangasala.	Silt clay	Silt clay	Silt clay	Silt clay	Root-crops	Root-crops	Kok-saghyz	Root-crops
Karjalohja	—	Heavy clay	—	—	—	Potatoes	—	—
Lahti	Heavy clay	Sand	Heavy clay	Sand	Cabbage	Cabbage	Cabbage	Cabbage
Leteensuo .	Peat pH5.2	Finesand clay	Finesand clay	Heavy clay	Grass	Potatoes	Sugar beets	Fallow
Maaninka .	Finer finesand pH 7.3	Finer finesand	Finer finesand	Finer finesand	Peas	Onion	Kok-saghyz	Kok-saghyz
Mikkeli ...	—	—	Sand	Sand	—	—	Flax	Potatoes
Mouhijärvi	Heavy clay pH 6.6	Finesand	—	Finesand	Sugar beets	Root-crops	—	Sugar beets
Nokia I ..	Silt clay	Silt	Silt	—	Clover	Wheat	Wheat	—
Nokia II ..	Finesand	Sand	Sand	Sand	Fallow	Sugar beets	Fallow	Root-crops
Porvoo ...	—	Heavy clay	—	—	—	Cucumber	—	—
Pälkäne ..	Sand pH 7.4	Sand	—	Sand	Potatoes	Tomatoes	—	Medicinal plants
Ruukki ..	Finesand clay	Finesand clay	Finesand clay	»	»	Vegetables	Poppy	Peas
Savio	Heavy clay pH 6.6	Heavy clay	Heavy clay	Heavy clay	Clover and timothy	Potatoes	Kok-saghyz	Tobacco
Siilinjärvi .	—	Finesand clay	—	—	—	Vegetables	—	—
Tammisto.	Sand pH 6.4	—	—	—	Potatoes	—	—	—
Tikkurila .	Heavy clay pH 6.0	Sand	Sand	Sand pH6.4	Autumn cereals	Flax	Wheat	Potatoes
» .	—	—	—	Sand pH5.8	—	—	—	Fallow
Vihti	Peat pH5.8	Peat	—	Peat	Potatoes	Flax	—	Potatoes
Ylistaro ..	—	Finesand clay	Finesand clay	Finesand clay pH5.8	—	Sugar beets	Peas	Root-crops

successful, but the yield was much lower than the yield obtained from mineral soils (cp. pp. 60—61).

The examined soils in experimental fields had a pH range from 5.2 to 7.4, mostly between 6 and 7, which must be considered suitable for the plant (cp. 82, p. 41).

[1])Cm = cattle manure.
+ = cattle manure was ploughed into the soil in autumn.
± = cattle manure was applied to previous crop.

and row spacing used for kok-saghyz plantings, 1943—1946.

Fertilization (kg. per ha.)																Row spacing (cm.)			
1943				1944				1945				1946							
Cm[1])	P_2O_5	K_2O	N	Cm	P_2O_5	K_2O	N	Cm	P_2O_5	K_2O	N	Cm	P_2O_5	K_2O	N	1943	1944	1945	1946
—	30	40	20	—	—	—	—	—	—	—	—	—	—	—	—	30	—	—	—
±	65	210	100	±	60	135	30	+	70	105	60	+	100	75	50	35	35	40	35
—	—	—	—	+	40	70	60	+	40	70	60	—	40	70	60	—	30	30	35
+	30	40	20	+	30	40	20	—	—	—	—	+	30	40	20	30	30	—	35
—	65	120	35	—	30	40	20	—	—	—	—	+	30	40	20	30	30	—	35
—	50	120	70	—	30	40	20	+	30	40	20	—	30	40	20	20	30	30	35
—	—	—	—	—	30	40	20	—	—	—	—	—	—	—	—	—	30	—	—
+	30	40	20	+	30	40	50	+	30	40	20	+	30	100	80	40	30	35	35
—	20	60	—	+	30	40	20	—	15	20	10	—	30	40	20	30	30	25	40
—	50	60	30	—	30	40	50	—	40	50	50	—	30	40	20	40	30	35	35
—	—	—	—	—	—	—	—	—	60	80	50	+	80	120	50	—	—	35	35
—	30	40	20	—	30	40	20	—	—	—	—	+	30	40	20	30	30	—	30
+	30	40	20	—	30	40	20	—	30	40	20	—	—	—	—	45	30	35	—
—	15	20	10	+	30	40	20	—	15	20	50	±	30	40	20	40	30	30	30
—	—	—	—	—	30	40	50	—	—	—	—	—	—	—	—	—	40	—	—
—	50	70	20	±	30	40	20	—	—	—	—	—	60	120	50	30	30	30	30
—	30	40	20	—	30	40	20	—	30	40	20	—	30	40	20	35	30	35	35
+	30	40	20	+	30	40	20	±	30	40	20	—	30	40	20	30	30	30	30
—	—	—	—	±	30	40	50	—	—	—	—	—	—	—	—	—	30	—	—
±	40	45	25	—	—	—	—	—	—	—	—	—	—	—	—	30	—	—	—
+	30	40	20	+	80	100	80	+	80	100	80	+	80	100	80	35	30	40	35
—	—	—	—	—	—	—	—	—	—	—	—	+	80	100	80	—	—	—	35
—	70	80	—	—	30	40	20	—	—	—	—	—	30	40	20	40	30	—	35
—	—	—	—	+	30	40	20	—	80	135	20	+	80	100	80	—	40	40	40

The fertilization applied to kok-saghyz plantings was, on the whole, rather poor except at Tikkurila and Fiskars (Table 9). This was mostly due to the war time shortage of fertilizers. Most experimental fields received only 30 kg. of P_2O_5, 40 kg. of K_2O, and 20 kg. of N per ha. The fertilizers were sent from Tikkurila to growth localities ready-weighed.

If kok-saghyz was grown as a biennial, the same amount of fertilizers as in the first spring was applied to the field in the spring of the second growing season.

Origin, germination, vernalization, and sowing of seed.

The seed used for the investigations on kok-saghyz in the years 1943—45 was bought from Germany in 1943. No accurate information as to the origin of the seed was available. The seed used in 1946—48 was produced in Finland. The native seed was collected from second year stands, and field tests were conducted with seed collected in the previous year. The origin, germination, and the rate of sowing of the seed used in field tests at Tikkurila and other experimental fields are given in Table 10. The seed used for the experiments was always treated with Ceresan.

Table 10. Origin, germination, and rate of sowing per ha. of the seed used for the field experiments on kok-saghyz in 1943—1947.

Year	Origin of seed	Germination % (untreated)[1]	Rate of sowing kg. per ha. (germinable seed)
1943	Germany	71	1.5
1944	»	58	1.7
1945	»	33	3.3
1946	Finland	75	2.3
1947 [2]	» (Fiskars)	69	—

In the first year the seed was not vernalized. In the following years part of the seed was vernalized according to the instructions issued in Germany (141, p. 11), which were based on the method of vernalization employed in U. S. S. R. (cp. 3, p. 22; 67). According to this method, cloth bags are filled with kok-saghyz seed to a quarter of their capacity, the bags are then closed and soaked in water for 3 to 4 hours to cause the seeds to swell. After this seeds are taken from water, the surplus water is drained away, and the seeds are placed in an ice cellar or in pits dug in the ground and filled with snow or ice, for 15 to 25 days. It is extremely important to prevent the seeds from becoming warm and to keep the temperature of the place of vernalization even and below + 2° C. After the period of vernalization the seeds are dried just enough to make sowing possible.

According to Russian instructions (3, p. 22), the temperature during vernalization should not fall below zero. It is also advised to wash the seed bags in fresh water once or twice during vernalization. At Tikkurila

[1]) = not vernalized.
[2]) Field tests only at Tikkurila.

vernalization of kok-saghyz seed was carried out in 1944 in a refrigerator furnished with a temperature regulator, in 1945—48 vernalization was carried out in open air in snow, and after thawing in an ice cellar. In March or April the seeds were buried in small cloth bags in a shady place in snow. Too rapid thawing and sudden changes in temperature were prevented by covering the place with alternate layers of sprigs of spruce and snow. Seeds were treated with Ceresan before vernalization.

Vernalization lasted for 15 to 30 days, but even longer periods were tested (see p. 38). The seed bags were turned over once a week during the period of vernalization, but they were not washed in water, as the seed had been treated with Ceresan. After vernalization the seed was dried at room temperature (14—18° C) over the night before sowing. In order to secure a uniform rate of sowing the seed was mixed with ungerminated seed of meadow fescue. Quickly growing flax was used to mark the rows. The ratio of mixture was 30 : 15 : 4 (meadow fescue, kok-saghyz, flax). Seed with very low germination was sown without using a filler, only a little flax was mixed with it. Sowing was done in single rows with Planet Junior drill. Rows were generally spaced 30 cm. apart, but also 45, 40, 35, and 20 cm. spaces were used (cp. Table 9). It was attempted to sow the seed at the earliest possible date in spring.

Management and harvesting.

In 1943—47 4—5 hand weedings and 5—6 harrowings were conducted on the first year plantings at Tikkurila. On over-winter plantings only one hand weeding and 3—4 harrowings were needed for weed eradication.

Early eradication of weeds on kok-saghyz plantings is considered extremely important. ALTUKHOV (4, p. 85) and others maintain that 3—5 days' delay in eradication of weeds may cause 30—50 % reductions in the yield. Also at Tikkurila it was noticed that shading by weeds considerably retarded the development of the plants (Fig. 4).

In experimental fields 2—3 weedings and harrowings, on the average, were conducted on the first year plantings in 1943—45. This is not sufficient for kok-saghyz plantings, but wartime shortage of labour made the management of experimental areas difficult. In 1946 the average number of weedings and harrowings during the growing season was somewhat higher, 3—4. The number varied on different plantings from 1 to 5.

Especially harmful weeds were some other species of dandelion, whose seed was mixed with the seed of kok-saghyz received from Germany. These rogues, however, were easily distinguishable from kok-

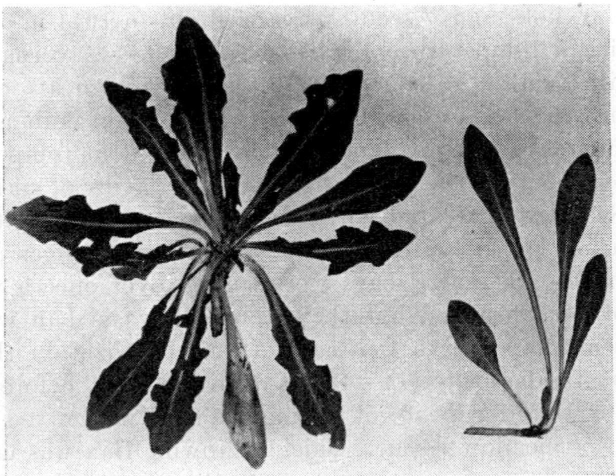


Figure 4. Injurious effect of shading by weeds. (On the left) Sound, normally developed rosette of kok-saghyz taken from a row weeded towards mid-July. (On the right) Rosette of the same stand taken from a row weeded two weeks later. (Orig.)

saghyz, because their growth was very rapid, size big, and their leaves were irregularly shallowly, but sharply, dentate (Fig. 20).

Thinning occurred only in 1943—44, when the plants were spaced 10 cm. apart within rows.

Harvesting was conducted by lifting kok-saghyz plants from the soil by means of a garden fork. Topping was done immediately after lifting by cutting the rosette of leaves at the crown, after which the roots were washed. For determinations of dry matter and rubber contents two root samples of 300 g. each were taken at Tikkurila from the total harvested lot immediately after topping and washing. In the experimental fields which were to be carried over to the following year the yield was determined on roots harvested from 5 row meters. The root samples were weighed after topping and washing as soon as the water had run away from the roots. At room temperature evaporation of water from the surface of the roots lasted for about an hour, if the roots were spread on the floor.

For first year stands the harvesting of roots, on which the yields per hectare given in Tables 24—27 (see pp. 60—63) were determined, was carried out at the latest possible date in autumn, mostly during October; for second year stands after flowering and seed formation at the end of July or beginning of August. Root yields are always given as yields of fresh roots.

3. Results of investigations.

a. *On the development and morphology of kok-saghyz plants.*

When kok-saghyz was grown for the first time in Finland, there was no experience as to its development under Finnish conditions. Therefore careful attention was paid to the different stages of development of the plant, such as germination, emergence, flowering, seed formation, dormant periods, and wintering. Most observations were made at Tikkurila, but observations on the most important stages of development were also made on several experimental fields in different parts of the country. Measurings and weighings were made for different stands in order to determine the size of the plant, and at the same time attention was paid to the most important morphological differences between different individual plants.

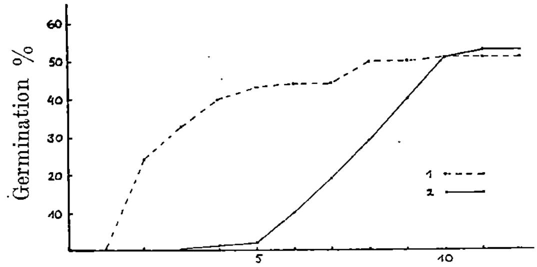
Germination and emergence.

One of the worst drawbacks in the cultivation of kok-saghyz is the long period of germination and poor emergence of the seed. AVSAREGOV (5, p. 51), when reporting his observations made on kok-saghyz plantings round Kursk during 11 years, mentioned that on the average only 28 % of the sown seed emerged in the fields, even if vernalized.

According to LYSENKO (67), the seed of kok-saghyz enters dormancy when drying after harvesting, and this accounts for the long germination and poor emergence of the seed. He thinks it necessary to vernalize the seed before sowing. Then germination begins within 5—6 days after sowing, and within 15 days all seeds have germinated, whereas untreated seed requires 2 or 3 times this number of days before germination is completed.

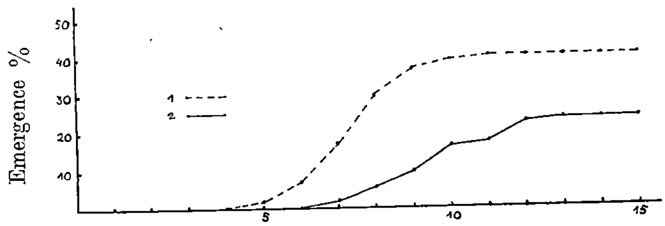
At Tikkurila the effect of vernalization was tested on the seed received from Germany in 1942, and on native seed. Determinations of germination were conducted in *Jakobsen's* germinator under changing temperature. Once a day the temperature in the germinator was raised up to 30° C, the temperature of the surroundings being 14—18° C. Three replicate germination tests were conducted with 100 seeds out of each investigated lot. Germination was usually carried on for 3 weeks.

When the seeds imported from Germany in 1942 were germinated in *Jakobsen's* germinator, the first sprouts appreared 3 days after the beginning of germinating, if the seed was untreated. Vernalized seeds showed signs of germination already after 1 day. At the same time as determinations of germination also determinations of emergence were conducted on the same lots of seed in the laboratory. The results of these experiments are given in Table 11 and in Figures 5 and 6.



Period of germination (days).

Figure 5. Germination of kok-saghyz seed after vernalization of 43 days (1), and untreated (2) (*Jakobsen*'s germinator).



Period of germination (days).

Figure 6. Emergence of kok-saghyz seed after vernalization of 43 days (1), and untreated (2), (pot experiments).

Table 11. Effect of vernalization on the germination and emergence of kok-saghyz seed in 1944.

Germinating begun April 28 1944	Period of vernalization (days)	Germination % after 2 days	Germination % after 14 days	Emergence % after 4 days	Emergence % after 14 days
Untreated	—	—	60	1	36
Vernalized	17	20	60	34	46
»	26	26	64	39	55
			F = 0.63		F = 93.6 ***; minimum significant difference 3.9

Germinating begun May 23 1944	Period of vernalization (days)	Germination % after 2 days	Germination % after 14 days	Emergence % after 4 days	Emergence % after 14 days
Untreated	—	—	54	—	22
Vernalized	26	17	54	—	41
»	43	24	51	—	40
	49	11	50	—	40
			F = 1.4		F = 25.7 ***; minimum significant difference 6.0

The results given in Table 11 indicate that the final germination percentage of the seed used in the experiments was not increased by vernalization, but the r a t e o f g e r m i n a t i o n w a s i n c r e a s e d, for in 2 days already 20 % of the seeds were germinated, whereas no germination was observed in untreated seeds by that time (Figures 7 and 8). The appearance of sprouts shows the effect of vernalization best. The results show that for untreated lots the percentage of emergence was only about 50 in 14 days, whereas the percentage was 80—85 for vernalized seed lots.

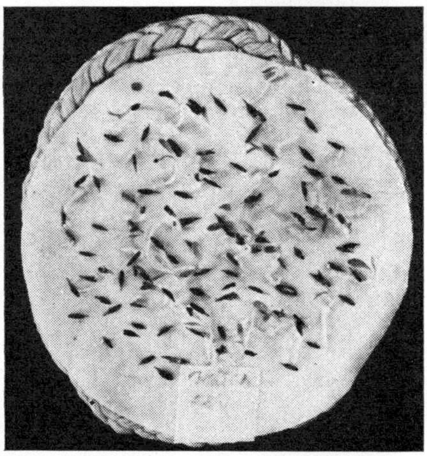


Figure 7. 100 vernalized seeds after 3 days' germinating. (Orig.)

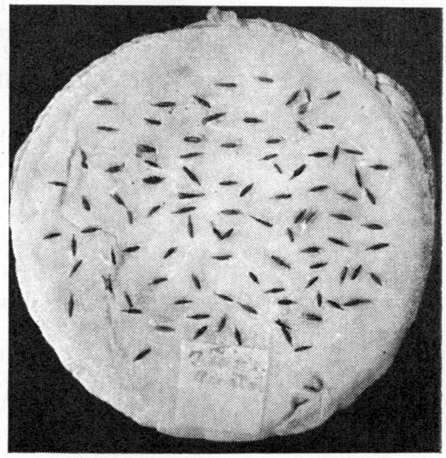


Figure 8. 100 untreated seeds after 3 days' germinating. (Orig.)

In 1945—48 native seed of kok-saghyz collected from second year stands was available. Vernalization was now carried out in snow or in an ice cellar (cp. p. 33). The results of these germination experiments are given in Table 12.

The reported results show that v e r n a l i z a t i o n r e s u l t e d i n a d i s t i n c t i n c r e a s e i n t h e g e r m i n a t i o n o f n a t i v e s e e d s.

When the effect of different periods of vernalization on the germination of kok-saghyz seed is examined, it can be observed that the period of vernalization should be at least 30 days, but in some cases the germinability of seeds was still increased if the period of vernalization was extended to 40—50 days. The results indicate that the germinability of the seed produced at different localities was increased by vernalization to different extents. Especially significant is the effect of vernalization in 1947 and 1948 on the germinability of the seed collected at Fiskars in 1946. In

Table 12. Effects of different periods of vernalization on the germination of seeds collected at different localities in the years 1945—1948.

Origin of seed	Period of vernalization (days)	Germinating begun	Germination	
			% after 21 days	relative number
	1945			
Fiskars 1944	untreated	May 11	**82**	**100**
»	20	»	93	113
F = 25.5 *; minimum significant difference 9.5.				
	1946			
Tikkurila 1945	untreated	May 11	**58**	**100**
»	24	»	76	131
F = 168.0 **; minimum significant difference 6.1.				
	1947			
Fiskars 1946	untreated	June 5	**47**	**100**
»	28	»	61	130
»	51	»	94	200
»	58	»	95	202
»	70	»	94	200
»	97	»	96	204
F = 201.6 ***; minimum significant difference 4.7.				
	1948			
Tikkurila 1947	untreated	May 4	**64**	**100**
»	32	»	85	133
F = 49.0 *; minimum significant difference 12.8.				
Tikkurila 1947	untreated	May 18	**64**	**100**
»	32	»	78	122
»	45	»	78	122
F = 11.3 *; minimum significant difference 9.5.				
Maaninka 1947	untreated	June 6	**73**	**100**
»	32	»	95	130
»	45	»	98	134
F = 434.8 ***; minimum significant difference 2.6.				
Fiskars 1947	untreated	June 6	**72**	**100**
»	32	»	79	110
»	45	»	92	128
F = 38.4 **; minimum significant difference 6.5.				
Hanko 1947	untreated	June 6	**84**	**100**
»	32	»	86	102
»	45	»	95	113
F = 33.5 **; minimum significant difference 4.1.				
Fiskars 1946	untreated	June 6	**46**	**100**
»	»	»	91	198
»	51 (1947) [1]	»	82	178
F = 264.5 ***; minimum significant difference 5.8.				

[1]) Vernalized seed stored dry for one year at 14—18° C.

1947 the percentage of germinability for seeds with 51 days' period of vernalization was twice the percentage of untreated seeds.

On the basis of these investigations it is difficult to state the exact reason for different effects of vernalization on seeds which are about the same age but have different origins. Some differences were noticed in the appearance of seeds. Seeds with uniform light green colour often showed weaker germination than brownish and slightly parti-coloured seeds. Weather conditions prevailing at the time of maturing and collecting of the seed probably account for the different colouring of seeds. If weather conditions at the time of maturing were very favourable, sunny and dry, and if the seed was cleaned and dried quickly after collection, seed of uniform light green colour was produced. These seeds usually required a long period of vernalization. On the other hand, if the seed, both before and after collection, was exposed to different temperatures and different moisture conditions, which did not damage the seed, the entrance of the seed into dormancy was possibly disturbed by these changes and the period of vernalization reduced.

It is evident that vernalization which affects the internal functions of the seed also softens the coats, thus making the germination process easier. The thickness of the seed coat is also dependent on the growth conditions of the plant and on storage after harvesting. Thus different thickness of the seed coat may largely account for the different effect of vernalization on seeds collected from different stands (cp. 133, p. 40).

The seed received from Germany was vernalized in the spring of 1944. The germination of the seed was not increased by vernalization in that year, and it was tested further in 1946 and 1947, and compared to the germination of untreated seed. The results of these germination tests are given in Table 13 and in Figure 9.

Table 13. Effect of storage [1] on the germination of vernalized and untreated seed in 1944—1947.

Period of vernalization (days)	Weight per 1 000 seed g.	Germination %				Imperfect germination %			
		1944	1945	1946	1947 [2]	1944	1945	1946	1947
Untreated	420	58	32	8	3	7	12	6	6
9	410	58	—	21	6	8	—	9	10
12	410	60	—	23	7	7	—	9	7
25	400	57	—	—	9	5	—	—	9
43	390	56	—	19	3	7	—	11	11

[1] Seed stored in cloth bags at room temperature (14—18° C).
[2] For the results of the germination experiments in 1947 F = 9.1 *; minimum significant difference 2.4.

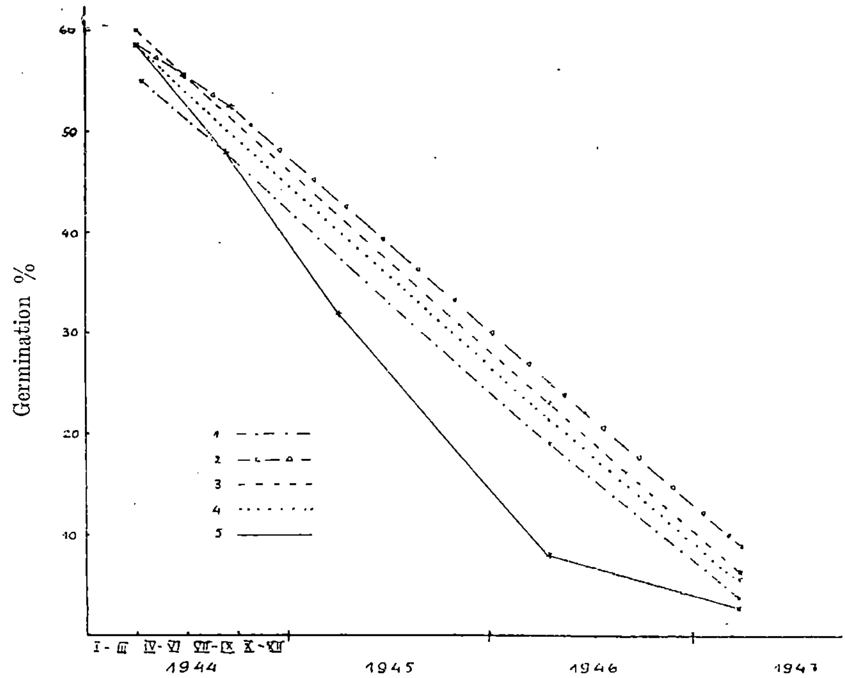


Figure 9. Decrease in germination of untreated and of vernalized seeds during the years 1944—1947. 1 = period of vernalization 43 days, 2 = 25 days, 3 = 12 days, 4 = 9 days, 5 = untreated seed.

Cotyledon seedlings without roots or with shrivelled roots were found in the germination tests. These are given in the last column of Table 13. Imperfectly germinated seeds are often found in germination tests of kok-saghyz, but usually their proportion is lower than 1 %.

It seems, however, that the proportion of imperfectly germinated seeds increases, if seeds are stored for long periods, or somehow injured. Also imperfectly germinated seeds are given in Figure 10, because in this case they, together with the seeds with normal germination, give the best picture of the viability of the seeds after three years' storage.

The results indicate that vernalization did not reduce the germinability of the seed, though the seed was dried and stored after vernalization, on the contrary, vernalized seed showed greater viability than untreated seed.

This opinion is also supported by the results given at the bottom of Table 12. According to them the increase in germinability caused by vernalization was practically unchanged after one year's storage under dry conditions. The increase in the rate of germination was not detectable after a year's storage.

Comparative cultivation tests with vernalized and untreated seed were conducted in connection with the dates of sowing experiments in order to find out the effect of vernalization on early and late sowings (see p. 76).

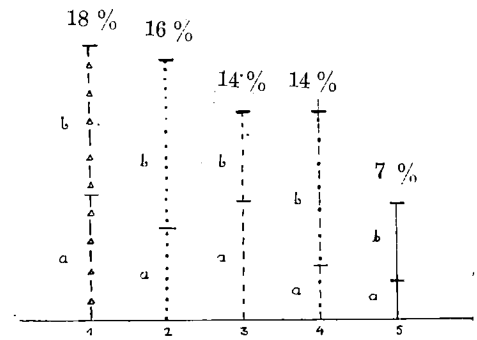


Figure 10. The viability of the seeds in the spring of 1947 after three years' storage. 1 = period of vernalization 25 days, 2 = 12 days, 3 = 9 days, 4 = 43 days, 5 = untreated seed. a = normally germinated seed, b = imperfectly germinated seed.

Observations on the emergence of kok-saghyz in the field were made during investigations both at Tikkurila and in experimental fields in different parts of Finland. Special attention was paid to the effect of vernalization on emergence. Table 14 shows the results of the experiments on the emergence of vernalized and untreated seed on sand soil at Tikkurila.

Table 14. Emergence of kok-saghyz on sand soil at Tikkurila in 1943—1947.

Year	Treatment of seed	Date of sowing	Date of emergence	Emergence begun (days after sowing)	Rate of sowing (germinable seed kg. per ha.)	Final density of stand (number of plants per row meter)
1943	Untreated	June 9	June 21	12	1.5	17
1944	Vernalized	May 14	May 24	10	1.7	27
»	Untreated	»	» 26	12	1.7	24
1945	Vernalized	» 26	June 4	10	3.3	50
»	Untreated	»	» 5	11	3.4	40
1946	Vernalized	» 11	May 19	8	2.4	68
»	Untreated	»	» 21	10	2.5	55
1947	Vernalized	» 9	» 17	8	6.2	80
»	Untreated	»	» 21	12	6.1	43

The observations made at Tikkurila with regard to the emergence of kok-saghyz and the effect of vernalization on emergence show that *the first seedlings appeared 10—12 days after sowing*, if *untreated seed* was used. The *first seed-*

lings on areas sown with vernalized seed appeared 1—4 days earlier, or 8—10 days after sowing. Figure 11 shows the emergence of vernalized and untreated seed on an experimental area at Tikkurila in 1946. As Figure 11 indicates, the period of emergence after the appearance of the first seedlings was 14 days for vernalized seed, and 25 days for untreated seed.

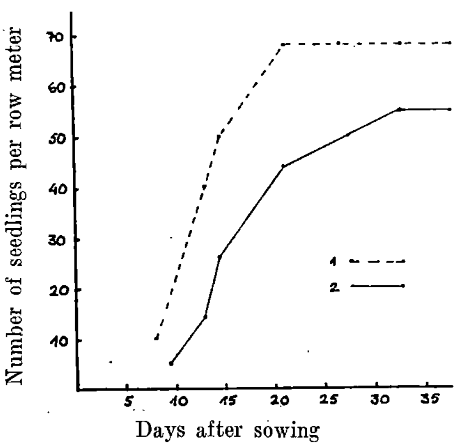


Figure 11. Emergence of vernalized (1) and untreated (2) seed in the field at Tikkurila. Sown May 11 1946.

Many observations show that temperature and moisture of the soil had considerable effect on the emergence. In 1944, owing to cold weather at the end of May, emergence at Tikkurila was not completed until 40 days after sowing for vernalized seed, and a week later for plantings sown with untreated seed. If sowing was followed by drought, the effect of vernalization appeared best. In 1947, for instance, the density of stands sown with untreated seed was at the end of emergence period only half of the density of stands sown with vernalized seed (Table 14). ZEHNGRAFF (138, ref. 133, p. 42) investigated in U. S. A. the value of vernalization in emergence. He reports that in one of his field tests an area sown with vernalized seed averaged 11.6 plants per linear foot 30 days after sowing, whereas an area sown with untreated seed only averaged 0.2 plants per linear foot.

Slow germination and emergence of kok-saghyz were also noticed in the experimental fields in different parts of Finland. Investigations as to the reasons for complete failure or very weak emergence on some areas showed the susceptibility of kok-saghyz to unfavourable germination conditions. For instance, drought or heavy rain occurring immediately after sowing proved unfavourable (cp. 133, p. 23). In smooth and light soils, such as peats, sowing was sometimes too deep, which delayed emergence and resulted in thin stands even under favourable weather conditions.

Kok-saghyz seeds were very susceptible to injury by fungi, especially at the stage of germination and emergence. Vernalization which reduces the period of germination and emergence protects the plant against such damage, at least to some extent.

Development up to the stage of flowering, flowering, and seed formation in first year stands.

As the emergence of kok-saghyz occurs very unevenly, usually within 20—40 days, the stands consist of plants differing from one another with regard to size and stage of development. As kok-saghyz is very sensitive to shading (cp. p. 34), later emerging seedlings are in dense stands shaded by the plants which have developed earlier. The result is further retardation in their development.

At all localities the development of kok-saghyz was slow after emergence. The first leaves were not formed until 2—3 weeks after emergence (Figures 12 and 13). Five weeks after emergence the number of leaves was 4—5, and the rosette formed by these was 5—10 cm. in diameter. ALTUKHOV (3, p. 10) reports similar observations on the development of kok-saghyz.

Figure 12. One month old seedlings of kok-saghyz (Natural size). (Orig.)

Observations were made on the development of kok-saghyz up to the stage of flowering in first year stands. In the years 1943—47 the first flowers appeared 58—83 days after sowing at Tikkurila, and 51—84 days after sowing in other experimental fields (Tables 15 and 16).

On the average, flowering began 67 ± 8[1]) days after sowing. The development of kok-saghyz up to flowering stage must be considered normal (cp. 3, pp. 9—10; 133, p. 17).

[1]) Standard deviation (146, p. 146).

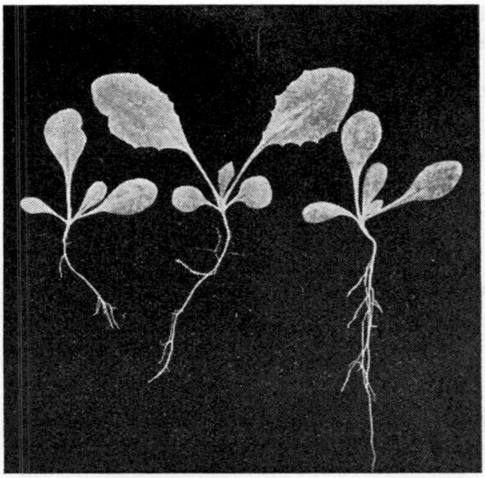


Figure 13. On right and left one month old seedlings of kok-saghyz, in the middle a seedling of common dandelion. (Orig.)

Unfavourable growth conditions, such as drought and shading by weeds, especially delayed the flowering of the plant. At Tikkurila it was observed that for late sowings flowering began relatively earlier than for early sowings. The plants which were sown early in spring, however, showed more vigorous development, as the yield of roots indicates (see p. 78). Comparisons between fields sown with vernalized and untreated seed showed that flowering in the former stands did not begin more than 1—2 days earlier than in the latter stands.

The geographical locality of the field did not seem to have any significant influence on the beginning of flowering. However, investigations conducted in U. S. A. have indicated that long day and cool climate are favourable for the early flowering of kok-saghyz (22, p. 107). In cultivation tests in U. S. A. the first flowers were noticed already 42—50 days after sowing in some first year stands, but one case is reported

Table 15. Flowering of first year kok-saghyz stands at Tikkurila in the years 1943—1947.

Year	Date of sowing	Date of beginning of flowering	Number of days from sowing to flowering	Diameter of rosette at height of flowering cm.	Height of flower scapes cm.
1943	June 9	Sept. 1	83	20	15
1944	May 14	July 22	70	30	20
»	» 29	Aug. 5	67	30	20
»	June 13	» 11	58	30	20
1945	April 30	July 20	80	30	25
»	May 16	» 27	71	35	25
»	» 26	» »	63	35	25
»	June 2	Aug. 3	61	35	25
»	» 4	» »	59	35	25
1946	May 11	July 15	64	25	15
»	» 21	» 22	61	25	15
»	June 4	Aug. 10	66	25	15
1947	May 9	July 10	62	20	10
		Average	67	30	20

Table 16. Flowering of first year kok-saghyz stands in experimental fields in the years 1943—1946.

Year	Number of fields	Number of days from sowing to flowering	
		Average	Range
1943	12	67	59—82
1944	18	65	51—81
1945	9	67	61—77
1946	18	67	54—84

when flowering did not begin until 90 days after sowing because of unfavourable weather conditions (133, p. 103).

Flowering continued in Finland until late in autumn and in most experimental fields flowering did not terminate until frost ended the growth period. Usually no dormancy was observed in kok-saghyz plants during the first summer. At Tikkurila plants turned yellow during the long droughts in 1946 and 1947, but recovered as soon as the moisture conditions of the soil improved.

Seed formation in first year stands was poor. Only few pollinating insects were seen because of scarce flowering of these stands and because of wet weather which is common in Finland towards the end of the growing season. Also in the investigations carried out in U. S. A. in 1943—44 poor seed formation in first year stands was noted (133, p. 104). The essential seed formation does not occur until the second growing season (3, p. 20).

Wintering.

Observations as to the development of kok-saghyz towards the end of the growing season showed that growth continued until very late autumn in spite of night frosts. The first night frosts at Tikkurila and in southern Finland generally occur towards mid-September.

Kok-saghyz stands usually suffered no damage though temperature fell to zero and —3° C. Leaves became reddish after night frosts and growth was retarded, but flowering continued. With further fall of temperature flowering gradually terminated, and most of the rosette wilted. Some green buds, however, were left in the centre of the rosette.

The resistance to frost of kok-saghyz was seen, for instance, in the autumn of 1946 at Tikkurila. The growth of kok-saghyz ended towards mid-October owing to several night frosts, when temperature fell to 10° C below zero. The soil remained frozen for several days after the frosts, but at the end of October it thawed again and remained unfrozen until mid-December. During November 1946 the plants developed rosettes, with a diameter of about 10 cm. The average temperature of the November of 1946 was 0.7° C, or 1.2° C higher than normal.

If growing season is long enough, the development of kok-saghyz is characterized by the formation of a new rosette after flowering. The plant winters at this stage. According to the Canadian investigators SCARTH, GOODING, and SHAW (123, p. 31), growing season must be 7 months long. This is not the case in Finland.

The observations made in Finland, however, indicate that the formation of a new rosette after flowering is not necessary. The new rosette can be formed at the beginning of the next growth period. Leaves begin to grow in spring as soon as thaw sets in. In 1945 chlorotic leaves had already developed under snow (Fig. 14).

Figure 14. Kok-saghyz stand at Tikkurila immediately after melting of snow April 14 1945. Chlorotic rosettes have developed under snow cover. Photograph by O. Valle.

Observations about wintering at different localities showed that kok-saghyz stands looked healthy and vigorous at the time of thawing. Loss of plants was not observed until April after disappearance of snow. The chief reason for this was frost heaving, owing to which thick branched roots were broken off and straight roots were pushed out of the soil. At some localities frost heaving of 5—6 cm. was observed in 1944. Heaving of 1—2 cm. was common, but it could not damage the plants. In 1946 and 1947 only slight root heaving (0.5—1 cm.) was observed at some localities.

In dense kok-saghyz stands where roots were thin because of inadequate growth space, broken roots were found only in the biggest plants. Root breaks occurred mostly near the crown, or, in branched roots, at the point where branches were attached to the taproot. The stretching capacity of thin and thick kok-saghyz roots was not tested, but KOKKONEN (56, pp. 38—39) found in experiments with rye roots that the stretching capacity is much higher for thin than for thick roots. From this it may be concluded that thin kok-saghyz roots may be more resistant to frost heaving than thick roots.

In addition to breaks caused by frost heaving also cracks were found in the cortical tissue of the plants. These cracks were evidently due to quick beginning of growth and to the abundance of water available to the plant in early spring. Cracks and root breaks were very susceptible to root-rot organisms which entered the roots at these points and caused serious rotting mostly resulting in complete destruction of the root.

At the Department of Plant Diseases, Agricultural Research Institute, no pathogenic species were found among these bacteria and fungi. But a species of *Sclerotinia* which was not more accurately determined caused some damage to leaves and crowns at Tikkurila, Maaninka, and Fiskars every year. Losses were greatest in 1944 and 1945 when the winters were milder than usual. *Sclerotinia* sp. and many other root-rot organisms attacked kok-saghyz stands worst in spring, if thaw set in early and the soil remained cold and wet for a long time, as occurred in the springs of 1944 and 1945.

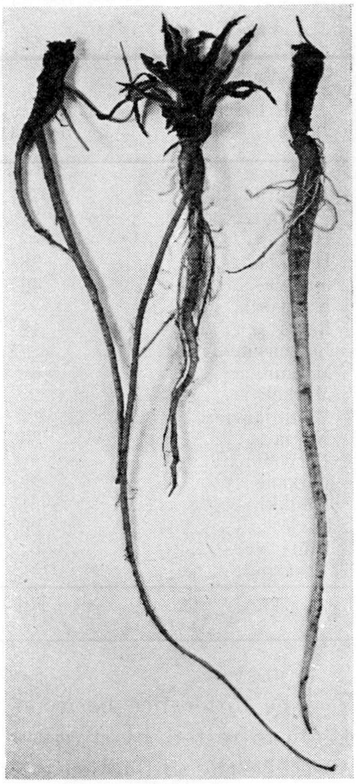


Figure 15. Roots from clay soil at Tikkurila after winter 1944. In the middle a sound plant, rosettes of the other plants rotten. Rotting continues in the root. (Orig.)

From the rosette the threads of fungi penetrated into the root and gradually rotted it (Fig. 15). If rotting was confined to 2—3 cm. below the ground surface roots resumed growth later in the spring. An adventitious bud was formed on the healthy part of the root and a new rosette of leaves developed. Usually the losses caused by *Sclerotinia* sp. were not higher than 10—15 % of the whole stand.

Losses in kok-saghyz stands were greatest after the mild winter periods of 1943—44 and 1944—45, as Table 17 giving percentages of wintering of stands indicates. The Data of Table 17 indicate distinct difference between winter losses occurring in the mild winters, and those occurring in the cold winters of 1945—46 and 1946—47.

It is probable that the better wintering of plantings in the winters of 1945—46 and 1946—47 is due to some other reasons as well, such as better conditions of the fields due to better cultural methods based on previous years' experiences. On the other hand, it is evident that kok-saghyz is best carried over through cold winters, which are characteristic of the native habitat of the plant. In central Europe, where winters are mild, only one third of the plants live over winter (141, p. 5). In U. S. A. the northern part having an annual average of 80 or more days with more than 1-inch snow cover proved to be the most favourable zone to wintering of kok-saghyz (133, p. 32).

In southern Finland temperatures of —30° C are unusual. E. g. in 1944 the lowest temperature in soil at Tikkurila was —23.5° C, in 1946 —30° C, and in 1947 (a winter with very little snow) —34.6° C. This shows that for a short period kok-saghyz resists even so low temperatures during winter.

Table 17. The wintering % [1]) of kok-saghyz stands in the years 1943—1947.

Locality	Wintering %			
	1943—44	1944—45	1945—46	1946—47
Tikkurila	70	44	88	94
Fiskars	31	39	71	100
Hanko	—	84	39	98
Hartola	38	100	—	100
Jomala	42	100	—	53
Kangasala	—	91	71	76
Lahti	12	82	—	100
Leteensuo	2 [2])	41	—	77
Maaninka	43	57	100	69
Mikkeli	—	—	64	78
Mouhijärvi	17	35	—	95
Nokia	33	100	—	100
Porvoo	—	31	—	—
Pälkäne	29	39	—	90
Ruukki	51	46	81	100
Savio	20	12	94	83
Vihti	—	25 [2])	—	53 [2])
Ylistaro	—	100	—	76
Average	Mild winter periods 49		Cold winter periods 82	

The difference between the means of percentages of wintering (Table 17) was tested by analysis of variance. Since the variance ratio F was 56.1***, the difference between the means must be said to be very significant.

The experiences in Finland in 1943—47 seem to indicate that kok-saghyz plantings are well carried over through winters with normal and below-normal temperatures.

[1]) The percentage of the density (plants per row meter) after winter as compared to the density before wintering.

[2]) Peat soils.

Development of kok-saghyz after winter.

After winter the growth of kok-saghyz started as soon as the ground was free from snow and the soil thawed. At Tikkurila this usually occurred towards the end of April. Numerous pale threads of roots were formed on the surface of the roots (Fig. 16), but they disappeared later in the spring.

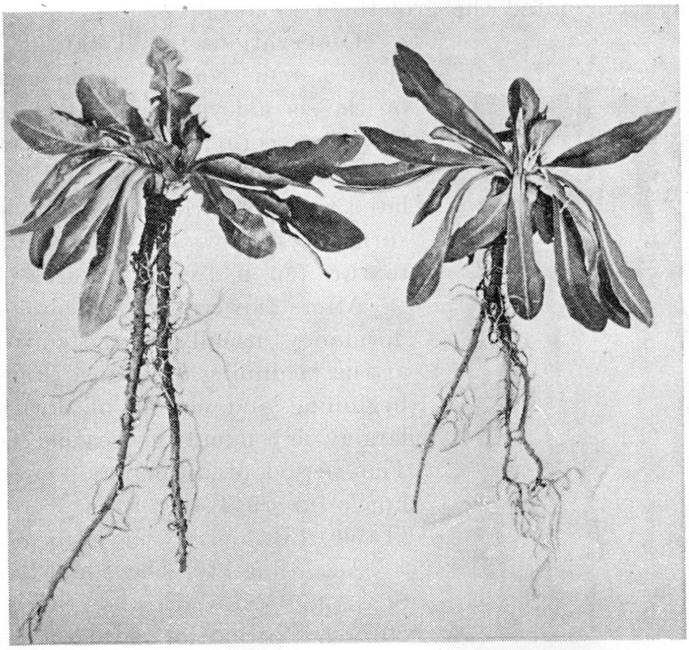


Figure 16. Second year plants at Tikkurila, May 15 1944. Fine threads on the roots disappear later in summer. (Orig.)

The quicker was the rise in the temperature of soil, the quicker was the development of kok-saghyz into flowering. After winter the flowering of kok-saghyz began one or two weeks before the flowering of the common dandelion *(Taraxacum officinale)*, which in 1943—47 occurred towards May 15—20 at Tikkurila. The height of flowering was reached about a month after the beginning of flowering, in southern and central Finland at the end of June or beginning of July. In the northernmost experimental field at Rovaniemi the height of flowering occurred in 1944 on July 20. In normal years weather conditions at the time of maximum flowering are favourable for the action of pollinating insects, and seed formation in second year stands was much more vigorous than in first year stands.

Observations as to the termination of flowering show that for second year plants flowering ceased at most localities towards the end of July. Thus the flowering period lasted for about 2 months, which must be considered normal (cp. 123, p. 30; 147, p. 4). On some plantings in southern Finland flowering continued until late August, but on these plantings the growth of kok-saghyz was usually very poor, owing to unsuitable soil or defective management resulting in vigorous growth of weeds which prevented the growth of kok-saghyz.

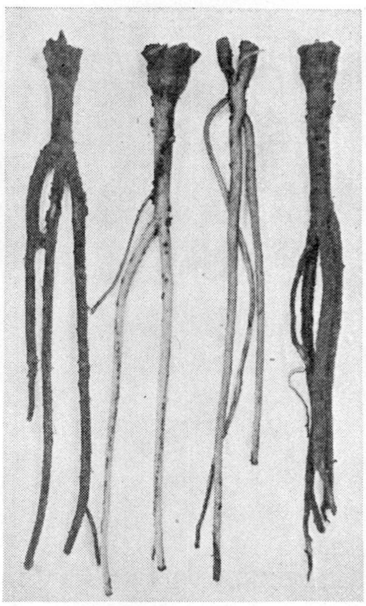


Figure 17. Roots of second year plants. In the middle old cortical tissue is washed off from the roots, new cortical tissue is visible. (Orig.)

Observations at Tikkurila indicated that a new cortical tissue was formed on the second year roots at the end of the flowering period. The old cortical tissue disintegrated gradually and the coagulated rubber-bearing latex was left on the surface of the old tissue in a netlike texture (cp. p. 19 and Figures 17 and 18).

After flowering the plants entered dormancy, usually at the end of July or at the beginning of August (Fig. 19). The beginning and ending of dormancy was largely dependent on weather conditions. The period of dormancy varied at Tikkurila in 1944—47 from 2 to 4 weeks (Table 18).

According to the investigations of Scarth, Gooding, and Shaw (123, p. 29), the period of dormancy lasted in Canada for 2—8 weeks. They paid special attention to the influence of environmental factors on dormancy. In their opinion kok-saghyz requires plenty of sunshine before it enters dormancy. Unfavourable conditions, such as drought, hasten dormancy. The Russian investigators Neuman and Sosnovetz (95) claim that dormancy can be postponed by shading, for instance. On the other hand, treatment

Table 18. Dormancy in second year kok-saghyz stands at Tikkurila in 1944—1947.

Year	Beginning of dormancy	End of dormancy	Precipitation (mm.)		
			June	July	August
1944	Aug. 25	Sept. 13	110.3	83.8	51.0
1945	July 20	Aug. 10	59.2	91.9	109.0
1946	» 19	» 20	63.7	25.6	36.3
1947	» 25	» 6	38.5	125.6	3.4

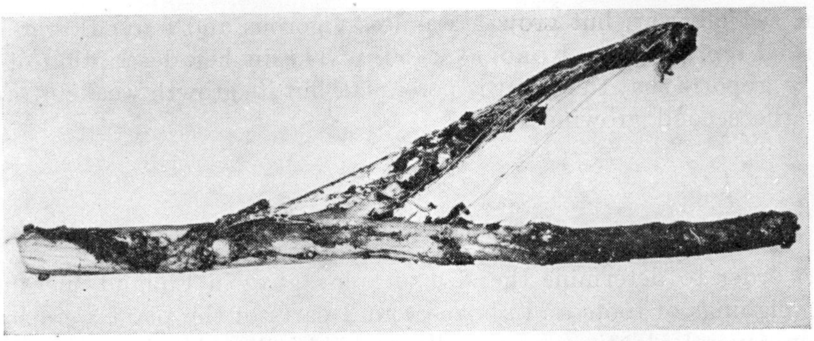


Figure 18. Old cortical tissue sloughing off from second year root at Tikkurila Aug. 20 1946. (Orig.)

Figure 19. Second year plants in dormancy after flowering in mid-August 1944. Photograph by O. Valle.

of roots with some kind of sugar solution resulted in dormancy earlier than usual (15).

After dormancy plants developed rosettes, 10—15 cm. in diameter, and wintered at this stage.

The development of kok-saghyz was observed at Tikkurila even in the third summer after sowing. It was similar to the development in the second year, but growth was less vigorous and fewer flowers were observed (cp. p. 105). Koroleva (59, p. 14), in her description of kok-saghyz, reports that the plant is perennial, but its growth weakens rapidly after the second growing season.

On the size and morphology of kok-saghyz plants.

In order to determine the size of kok-saghyz in Finland, measurings and weighings of roots and above-ground parts of the plant were carried out on several plantings, especially at Tikkurila. Also in experimental fields attention was paid to the growth of the above-ground parts of the plants, and measurings were made both in the first and in the second growing season.

Table 19 gives the average results of measurings and weighings conducted during the years of investigations in different experimental fields at time of maximum flowering.

Table 19. Measurings of the average size of above-ground parts of different kok-saghyz stands in the first growth summer, in the years 1943—1946.

Year	Number of localities	Diameter of rosette (cm.)		Height of flower scapes (cm.)	
		Average	Range	Average	Range
1943	17	23	15—35	—	—
1944	22	20	10—30	20	6—30
1945	11	24	13—35	18	6—25
1946	19	29	7—35	16	7—30

Kok-saghyz plants reached the maximum size in June or July in the second growth summer (Table 20). The diameter of the rosette was not much greater, but the number of leaves and flower scapes in a rosette was considerably higher than in the summer of sowing.

Table 20. Measurings of the average size of above-ground parts of kok-saghyz plants in the second growth summer in 1944—1945.

Year	Number of localities	Diameter of rosette (cm.)		Height of flower scapes (cm.)	
		Average	Range	Average	Range
1944	14	28	15—40	26	8—40
1945	14	25	15—40	—	—

When root samples were taken in 1943—44 at Tikkurila and Tammisto, the above-ground parts and roots were also measured and weighed. Only about 20 roots were analyzed for each experimental area, but this amount was considered sufficient to give a picture of the plants. The results are given in Table 21. At Tikkurila 2 analyses were made for the same stand, the first on October 2 1944, and the second three weeks later, on October 23, which shows the stage of plants at the end of the first growing season. Also for the second year plants weighings and measurings were carried out at different dates.

These measurings and weighings show that the examined stands consisted of widely different individuals. For the first year stands the weight of roots ranged from 2 to 18 g., for the second year stands from 4 to 40 g. The length of the roots ranged from 11 to 28 cm. In soft sand soil roots penetrated somewhat deeper than in clay soil. Roots with 40—50 cm. long branches were also encountered, but they were extremely unusual. Very few branches occurred in the roots, only 1 or 2 per root.

The diameter of the root at the crown ranged from 0.4 to 2.0 cm. for first year plants. Roots of some second year plants were 2.5 cm. in diameter at the crown. The thickness and the weight of the roots were largely dependent on the density of the stand. The measurings given in Table 21 were made for stands with rows spaced 30—40 cm. apart. The density in rows varied from 10 to 35 plants per row meter. In 1945—47, when the rate of sowing was higher than in 1943—44, roots were on the average lighter and thinner than during the first years of experiments (see Tables 24—27, root weights), but even then roots from the same stand had different weights, small roots, 0.5—3 g. in weight, forming the majority.

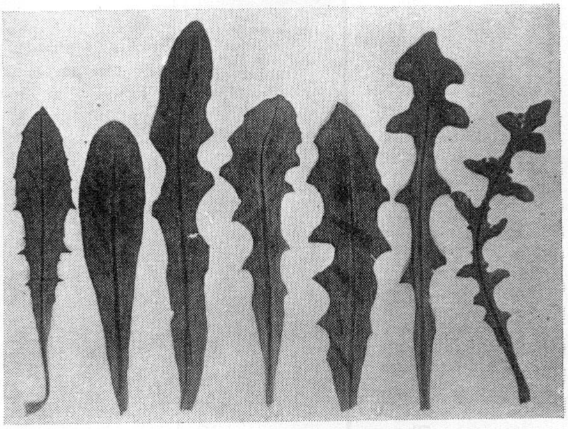


Figure 20. Kok-saghyz leaves of different forms from second year stand at Fiskars July 11 1944. The first on the left a small leaf of a type of rogues (cp. pp. 33—34). (Orig.)

The greatest differences between individual plants were noticed with regard to the weight of the rosette, leaf form, and flowering. The margins of leaves ranged from entire to sharply incised (Fig. 20). Sometimes there were leaves with both entire and incised margins on

Table 21. Results of measurings and weighings for first and second year kok-saghyz stands in the years 1943—1944.

Locality and soil	Date of sowing	Date of sample	Number of measured plants	Number of plants per row meter	Weight of root g.		Weight of rosette g.		Length of root cm.		Diameter of root at crown cm.		Diameter of rosette cm.		Number of sound, fully-developed leaves per plant		Number o flower scapes per plant [1]	
					Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
First year stands																		
Tammisto .. (sand soil)	June 9 1943	Sept. 24 1943	24	14	8	3—18	36	10—138	21	11—26	0.9	0.5—1.7	32	22—36	36	13—100	15	6—25
Tikkurila ... (clay soil)	May 25 »	Oct. 2 »	13	9	7	2—15	20	2— 80	19	16—24	0.8	0.4—1.1	39	24—36	26	12— 56	17	9—23
Tikkurila ... (sand soil)	May 14 1944	Oct. 2 1944	20	23	8	4—16	20	6— 78	23	18—28	1.1	0.8—2.0	31	25—40	22	10— 68	8	5—15
	»	» 23 »	20	27	7	4—15	8	1— 17	23	15—27	1.0	0.4—1.9	15	0—24	12	0— 24	4	1—6
Second year stands																		
Tikkurila ... (clay soil)	May 25 1943	Aug. 9 1944	20	10	12	4—40	35	4—138	17	15—22	1.2	0.5—2.2	33	26—40	28	4— 72	15	1—59
	»	» 16 »	20	11	10	4—20	6	0— 12	19	9—24	1.5	0.9—2.5	13	6—16	10	2— 22	—	—
Tikkurila ... (sand soil)	June 17 »	July 15 »	20	35	3	2—10	28	8— 67	22	17—27	0.9	0.5—1.5	24	22—44	20	8— 49	12	1—28
	»	Aug. 8 »	20	20	5	4—12	23	3— 40	23	15—26	0.9	0.6—1.7	30	20—40	16	5— 35	3	0—22
	»	Sept. 13 »	20	26	6	3—16	7	1— 21	21	13—26	1.0	0.5—1.9	21	0—30	11	0— 35	—	—

[1]) Number of flower scapes includes scapes bearing seed heads or buds.

the same plant, but this was unusual. Therefore it was difficult to classify kok-saghyz plants on the basis of leaf form.

The size of rosette was largely dependent on the density of stands. In thin stands the rosette of some second year plants was 40—45 cm. in diameter, the breadth of leaves at the widest point 2—2.5 cm., the total weight of the rosette 140—150 g., and the number of fully-developed leaves 130—150.

In 1943 the weight of the rosette for first year stands at the end of September, or beginning of October averaged 31.5 g. (14 experimental fields), the density being 9—10 plants per row meter. In 1946, with the density of 30 plants per row meter, the weight of the rosette averaged only 6.3 g. (19 experimental fields). The corresponding average weight of one root was 8.6 g. in 1943 and 3.7 g. in 1946.

For dense stands which averaged 36 plants per row meter the average weight of the rosettes was only 20 % of the corresponding weight for thin stands (10 plants per row meter), and the weight of roots 43 % of the corresponding weight for thin stands. The density of the stands seems to have reduced the growth of above-ground parts more than the growth of roots, which must be considered useful for the culture of kok-saghyz.

Part of the plants flowered already in the summer of sowing, part of them did not flower until the second summer (Fig. 21). At Tammisto and Tikkurila the number of flower scapes on plants flowering in the first year was in 1943 15—17, the density being 10 plants per row meter. In 1944 the stand on sand soil at Tikkurila developed in the first summer only 10 flower stalks per plant, the density ranging from 20 to 30 plants per row meter. Under favourable conditions (in thin stands) some plants developed up to 40—50 flower stalks in the first summer.

Flowering was more abundant in the second growing season. Occasionally, e. g. at Fiskars in 1944 some plants developed more than 100 flower stalks. The number of flower stalks for the second year given in Table 21 does not give a correct picture of the height of flowering, as the determinations were conducted in connection with root harvesting when the height of flowering was already over.

Attempts to determine for the stands the proportion of plants flowering in the first year proved difficult in the fields, because under normal conditions plants are so close to one another that part of the plants were not able to reach flowering stage during the first season owing to lack of growth space. For dense stands (20—30 plants per row meter) the proportion of flowering and non-flowering plants was therefore determined by ignoring small non-flowering plants whose small size was evidently due to lack of growth space. The results are given

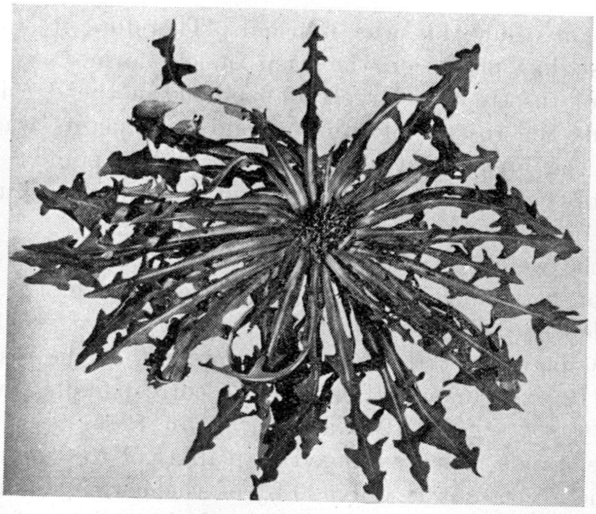


Figure 21. Rosette of typical kok-saghyz plant flowering in the second season. Photograph taken in late summer. (Orig.)

in Table 22. Measurings were made in autumn in connection with the dates of harvesting experiments, and results are from three different dates for the same stand. Each time about 200 plants were weighed, and the number of flowering and non-flowering plants was counted after weighing.

Table 22. Proportion of flowering and non-flowering plants in a dense stand during the first growing season at Tikkurila in 1944.

Date of harvesting and type of plant	% of the stand	Average root weight g.	Average weight of rosette g.	Ratio between weight of roots and weight of rosettes
Tikkurila 1944.				
October 9				
Non-flowering	33.2	6.6	9.8	1:1.5
Flowering	34.1	4.7	8.9	1:1.9
Small plants	32.7	2.0	1.6	1:0.8
October 16				
Non-flowering	23.6	8.3	11.8	1:1.4
Flowering	37.4	5.5	8.9	1:1.6
Small plants	39.0	1.4	0.8	1:0.6
October 23				
Non-flowering	22.7	10.3	9.3	1:0.9
Flowering	35.7	5.3	4.4	1:0.8
Small plants	41.6	1.4	0.6	1:0.4

In 1944 stands were also established at Tikkurila from seedlings planted at 10 cm. apart. On October 25 the proportion of the plants flowering in the first season was determined on 200 of these plants. The result was 45.7 %. When average individual root weights were compared, non-flowering plants were found to possess larger roots. The average root weight was namely 15.4 g., for flowering plants 10.0 g. In 1945 the proportion of flowering and non-flowering plants was determined three times on a stand established from seedlings planted May 17 1945. The density of the stand was about 15 plants per row meter. The sample was taken from 4 row meters. The results are given in Table 23. Table 23 also gives the results of measurings and weighings carried out at Tammisto on October 22 1943 for a stand thinned to 10 cm. spaces between plants.

Table 23. The proportion of flowering and non-flowering plants in a thin first year stand at Tammisto in 1943, and at Tikkurila in 1945.

Date of harvesting and type of plant	% of stand	Average root weight g.	Average weight of rosette g.	Ratio between weight of roots and weight of rosettes
Tammisto 1943.				
October 22				
Non-flowering	43.4	7.6	12.2	—
Flowering	56.6	5.1	11.7	—
Tikkurila 1945.				
September 14				
Non-flowering	55.6	11.4	17.7	1:1.6
Flowering	44.4	5.3	19.6	1:3.7
September 28				
Non-flowering	50.0	13.3	21.2	1:1.6
Flowering	50.0	10.0	19.1	1:1.9
October 12				
Non-flowering	49.3	14.6	15.4	1:1.1
Flowering	51.7	7.0	9.8	1:1.4

Tables 22 and 23 indicate that *about 50 % of the plants flowered in the first season*. The same result was also obtained for dense stands (25 plants per row meter), if the plants suffering from lack of growth space were eliminated. In addition it was observed that *non-flowering plants developed larger roots than flowering plants*. The rosettes of non-flowering plants remained green until late autumn, whereas the average weight of the rosette of flowering plants was reduced by one half during the time between the two last samples. Thus growth was more vigorous in the non-flowering than in the flowering plants late in autumn, which is also indicated by the increase in root weight.

Determinations of rubber content in 1943 did not indicate any significant difference between the roots of flowering and non-flowering plants.

Similar results were obtained in U. S. S. R. in investigations on unimproved plants. NEUMAN and AVSAREGOV (94, p. 19) report, when comparing various improved kok-saghyz stands to unimproved stands, that the proportion of flowering plants was 53.3 % in the first season. KUPZOW (62) and MASHTAKOV (77) investigated the value of flowering and non-flowering plants in the first growing season and found that non-flowering plants develop larger roots. From the beginning of investigations, plants flowering in the second growing season have been considered superior to those flowering in the first growing season (cp. 96, p. 217) with regard to cultural value. Different opinions have been expressed later (cp. 78), but the original conception of the cultural value of plants which do not flower in the first season must be considered right.

b. *Yields and some factors affecting them.*

Kok-saghyz plantings are mostly established by sowing seeds in rows in the field early in spring. In U. S. S. R. good results have also been achieved by group sowing (cp. 2; 68; 111), but this method has not received attention in other countries, as sowing must be done by hand and thus plenty of manpower is required at sowing time. Kok-saghyz is grown both as an annual and as a biennial.

In U. S. S. R. kok-saghyz plantings were also established by planting seedlings. Seedlings were planted either in rows or in groups (3, p. 24). Establishment of kok-saghyz plantings by vegetative propagation has been investigated in many countries, especially in U. S. S. R. (35; 43; 69; 72; 85; 151).

Following methods were tested in Finland in 1943—47: 1) sowing in the field (in single rows) as an annual or as a biennial 2) planting of seedlings (singly in rows), 3) vegetative propagation.

Field sowings.

Sowing of kok-saghyz seeds in the field is the usual method of establishing large plantings for rubber production. Therefore all experimental fields and most of the test fields at Tikkurila were established in this way. Sowings were accomplished early in the spring. In the autumn of 1944 also autumn sowing was tested at Tikkurila, but results were so negative that experiments were not continued. On the basis of many years' experiences autumn sowing is considered in U. S. S. R. much more uncertain than spring sowing (5, p. 53).

Tables 24—27 (pp. 60—63) give the yields of 1943—47 from all successful (cp. p. 22) experimental fields, which delivered adequate information for first and second year stands. For this reason the number of experimental areas given in the Tables 24—27 differs from the number of successful experimental areas given in Table 1. Also the yields obtained from field sowings at Tikkurila during the same years are included in the Tables.

It was thought necessary to report the average density of each stand (plants per row meter) and the average root weight (g.) in addition to the yields. Information about the density illustrates the wintering of the plantings and average root weight indicates the development of the roots during the second growth summer.

Rows were spaced 30—45 cm. apart (cp. Table 9). In tables 24—27 the results are arranged according to the yields from first year stands so that the highest yields are reported first.

The yields reported in Tables 24—27 were obtained from experimental fields on sand or clay soil with high organic content. Only the experimental field at Leteensuo in 1943 and at Vihti in all the other years were located on peat soils (cp. pp. 30—31 and Table 9).

A survey of Tables 24—27 shows great fluctuations in the yields of root and rubber obtained from first and second year stands in different years.

The yields obtained in the two first years were considerably lower than those obtained in later years. This is probably largely due to different density of stands, which was in the first place determined by the amount of seed used for sowing, by methods of sowing, and management of stands (cp. pp. 32—34). In 1945—46 the rate of sowing was nearly twice that of 1943—44, and methods of sowing and cultivation were better, because advantage could be taken of the experiences of the first years. Therefore the density of the stands was in 1945—46 twice that of 1943—44.

Russian investigators observed that kok-saghyz thrives best in dense stands, and therefore group sowing is there considered very suitable for kok-saghyz (cp. p. 58). In Finland the seed was sown in rows on the same area in 2 or 3 lots in order to secure as even sowing as possible. Therefore the rows were somewhat wider than usual, which evidently favoured the development of kok-saghyz.

Table 24. Yields of kok-saghyz from first and second year stands in 1943 and 1944. Sown in spring 1943.

Locality	Growth period (days)	Date of harvesting		Yield of roots kg. per ha		Number of plants per row meter		Average root weight g.		Dry matter %		Rubber in dry matter %		Rubber in fresh weight %		Rubber kg. per ha.	
	1943	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944	1943	1944
Fiskars	143	Sept. 28	Aug. 9	3 710	3 300	9.0	4.6	14.4	25.0	23.4	25.0	5.8	9.5	1.4	2.4	52	79
Ruukki	134	Oct. 1	July 24	3 650	1 670	18.0	5.6	7.2	10.9	24.7	24.0	7.3	12.4	1.8	3.0	66	50
Pälkäne	137	» 2	» 24	3 060	950	7.3	2.1	12.0	13.9	23.2	21.5	8.0	10.0	1.9	2.2	58	21
Mouhijärvi .	113	Sept. 10	» 31	2 500	400	7.7	1.3	9.7	17.0	29.0	24.9	5.4	8.8	1.6	2.2	40	9
Maaninka ..	137	Oct. 1	» 20	2 500	1 450	6.5	2.8	14.3	22.9	24.5	21.3	5.7	12.7	1.4	3.3	35	47
Tammisto ..	149	Nov. 5	Aug. 7	2 470	430	14.0	2.6	5.4	10.0	25.5	22.6	6.3	8.2	1.6	1.9	40	8
Hartola	151	Oct. 10	July 25	2 330	1 640	5.5	2.1	12.1	25.5	25.6	20.1	8.9	14.9	2.3	3.0	54	49
Rovaniemi ..	127	» 1	» 29	2 260	1 260	11.0	2.8	6.7	16.6	25.2	24.2	5.6	9.5	1.4	2.3	32	29
Nokia I	123	Sept. 14	» 25	2 180	1 790	9.0	3.0	10.0	26.9	22.8	20.0	6.0	13.3	1.4	2.7	31	48
Lahti	134	Oct. 2	» 15	2 180	350	14.0	1.2	6.2	11.9	20.9	20.5	6.0	16.7	1.3	3.5	28	12
Jomala	183	Nov. 6	» 25	1 670	890	5.0	1.2	10.0	24.4	26.8	20.4	8.3	12.0	2.2	2.5	37	22
Savio	143	Oct. 2	» 28	1 380	730	12.0	2.4	2.7	8.9	21.2	26.0	4.9	6.2	1.1	1.7	15	12
Leteensuo ..	153	» 15	» 27	1 000	70	6.0	0.1	5.4	4.7	23.4	23.0	9.4	12.5	2.2	2.9	22	2
Tikkurila ...	130	» 2	Sept. 16	1 000	2 050	9.0	6.3	3.9	10.9	24.9	23.4	6.0	10.1	1.5	2.4	15	49
Average	140			2 280	1 210	9.6	2.7	8.6	16.4	24.4	22.6	6.7	11.2	1.7	2.6	38	31

Table 25. Yields of kok-saghyz from first and second year stands in 1944 and 1945. Sown in spring 1944.

Locality	Growth period (days)	Date of harvesting		Yield of roots kg. per ha		Number of plants per row meter		Average root weight g.		Dry matter %		Rubber					
												in dry matter %		in fresh weight %		kg. per ha.	
	1944	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945	1944	1945
Tikkurila ...	162	Oct. 23	July 24	4 340	3 430	27.4	12.1	4.7	8.5	25.4	29.4	7.8	9.5	2.0	2.8	87	96
Hanko	148	» 14	Aug. 6	2 800	2 630	7.7	6.5	10.7	12.1	23.5	29.3	8.5	11.7	2.0	3.4	56	89
Porvoo	144	» 18	» 2	2 650	1 510	13.9	4.5	5.8	10.5	22.6	26.8	7.6	12.7	1.7	3.4	45	51
Ruukki	142	» 18	» 3	2 650	3 080	21.7	10.0	3.7	9.2	29.7	29.0	6.5	12.5	2.0	3.6	53	111
Fiskars	133	» 11	» 7	2 500	1 970	14.0	5.5	6.3	12.5	23.4	30.6	6.8	11.7	1.4	3.5	35	69
Leteensuo ..	135	» 17	» 3	2 430	2 940	15.8	6.5	4.6	13.6	25.9	28.3	5.8	10.2	1.5	2.9	36	85
Pälkäne	142	» 16	» 4	2 310	2 400	13.7	5.3	9.6	15.8	20.3	28.5	6.6	10.4	1.4	3.0	32	72
Maaninka ..	139	» 16	» 2	2 290	2 780	13.2	7.5	5.3	13.0	23.2	26.4	6.2	14.0	1.5	3.7	34	103
Mouhijärvi ..	149	» 20	» 2	1 950	1 630	8.5	3.0	6.8	16.3	22.3	25.3	5.0	7.0	1.1	1.8	21	29
Siilinjärvi ..	146	» 10	» 1	1 710	1 640	7.5	4.7	6.9	10.5	26.0	31.4	5.5	12.0	1.4	3.8	24	62
Nokia I	144	» 18	July 30	1 700	3 040	5.2	6.0	9.8	15.2	24.7	23.2	6.2	11.8	1.5	2.7	26	55
Hartola	138	» 13	Aug. 2	1 520	2 300	5.3	5.3	8.6	13.0	24.8	27.2	6.5	13.1	1.7	3.6	26	56
Savio	141	» 17	» 6	1 520	1 000	4.8	4.0	7.9	10.0	26.8	25.6	5.3	8.6	1.4	2.2	21	22
Vihti	143	» 16	» 6	1 420	680	5.5	1.4	7.8	14.5	26.0	24.0	7.3	9.6	1.9	2.3	27	16
Nokia II ...	143	» 17	» 8	1 300	1 500	8.2	4.1	4.8	11.0	24.3	29.7	6.5	12.5	1.6	3.7	21	56
Lahti	168	Nov. 10	July 29	1 040	1 400	4.5	3.7	7.7	11.5	21.6	23.6	8.9	13.2	2.0	3.1	21	43
Jomala	151	Oct. 24	Aug. 7	1 030	2 550	3.8	4.6	8.3	16.7	24.0	29.9	7.7	12.7	1.9	3.8	20	97
Karjalohja ..	156	» 30	» 3	810	1 430	16.1	10.0	1.5	5.7	20.3	29.7	8.9	10.7	1.8	3.2	15	46
Ylistaro	142	» 16	» 22	750	2 000	2.8	2.8	8.2	21.0	25.2	24.6	5.5	9.7	1.4	2.4	11	48
Kangasala ..	149	» 21	» 7	610	1 560	4.5	4.1	4.2	15.0	22.6	26.3	6.9	9.8	1.6	2.6	10	41
Average	146			1 870	2 070	10.2	5.6	6.7	12.8	24.1	27.4	6.8	11.2	1.6	3.1	31	62

Table 26. Yields of kok-saghyz from first and second year stands in 1945 and 1946. Sown in spring 1945.

Locality	Growth period (days)	Date of harvesting		Yield of roots kg. per ha		Number of plants per row meter		Average root weight g.		Dry matter %		Rubber in dry matter %		Rubber in fresh weight %		Rubber kg. per ha.	
	1945	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946	1945	1946
Tikkurila ...	138	Oct. 11	Aug. 5	5 480	4 580	40.5	35.5	5.4	5.2	25.2	30.7	7.3	12.3	1.8	3.8	99	174
Maaninka ...	138	» 4	July 31	3 770	3 860	18.0	18.0	7.8	7.4	27.2	26.0	5.8	16.1	1.6	4.2	60	162
Hanko	138	» 2	Aug. 3	3 570	2 170	11.4	4.4	11.0	17.3	24.3	25.5	5.4	12.0	1.3	3.1	46	67
Fiskars	148	» 5	July 31	3 290	3 540	16.6	11.8	6.9	10.5	26.9	28.8	4.5	12.6	1.2	3.6	39	127
Kangasala ..	132	» 9	Aug. 10	3 130	3 830	24.8	17.6	3.8	6.5	27.2	28.5	5.6	13.5	1.5	3.8	47	146
Savio	124	» 1	July 31	3 000	2 980	17.0	16.0	5.4	5.6	24.5	28.0	4.8	12.7	1.2	3.6	36	107
Ylistaro	141	» 5	» 30	2 800	3 800	17.2	13.0	6.5	11.7	24.6	26.7	5.2	9.3	1.3	2.5	36	103
Mikkeli	127	» 4	Aug. 1	2 630	2 540	23.8	15.3	3.9	5.8	27.3	23.1	5.5	11.6	1.5	2.7	39	41
Ruukki[1]) ..	128	» 3	July 10	1 540	2 720	13.8	11.2	4.2	9.1	26.4	24.1	5.3	12.1	1.4	2.9	22	79
Nokia I	126	» 3	» 31	1 380	—	10.4	—	5.3	—	23.8	—	4.7	—	1.1	—	15	—
Average	134			3 250	3 340	20.3	15.9	6.1	8.8	26.0	26.8	5.5	12.5	1.4	3.4	47	112

[1]) Not included in the average.

Table 27. Yields of kok-saghyz from first and second year stands in 1946 and 1947. Sown in spring 1946.

Locality	Growth period (days)	Date of harvesting		Yield of roots kg. per ha.		Number of plants per row meter		Average root weight g.		Dry matter %		Rubber in dry matter %		Rubber in fresh weight %		Rubber kg. per ha.	
	1946	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947	1946	1947
Tikkurila a ..	144	Oct. 12	Aug. 6	7 890	7 620	94.8	89.0	2.9	3.0	25.0	24.6	7.1	10.4	1.8	2.6	142	198
» b ..	150	» 8	» 6	5 180	7 050	36.5	33.5	5.0	7.4	25.3	26.2	7.1	11.1	1.8	2.9	93	204
Ylistaro	143	» 15	» 11	5 690	5 300	34.0	32.0	6.7	6.6	27.2	32.7	5.8	11.6	1.6	3.8	91	201
Mouhijärvi ..	143	» 15	» 5	5 170	5 770	45.0	42.8	3.4	3.7	25.0	27.3	9.4	14.5	2.4	4.0	124	231
Jomala [1]).... (sand soil)	138	» 9	» 15	4 730	—	22.8	—	6.8	—	22.6	—	7.3	—	1.7	—	80	—
Maaninka ..	140	» 8	» 7	4 540	4 940	55.8	38.6	2.8	4.5	25.1	26.2	7.5	13.7	1.9	3.6	86	178
Savio	145	» 13	» 14	4 330	4 270	24.0	20.0	5.4	6.4	27.7	31.2	6.9	13.0	1.9	4.1	82	175
Lahti	142	» 14	» 7	4 260	5 200	54.2	54.6	2.7	6.7	24.9	25.6	8.0	12.3	2.0	3.1	85	161
Hartola	137	» 5	» 18	4 110	3 860	52.0	55.0	2.8	2.4	28.0	27.0	8.7	13.5	2.4	3.6	99	139
Mikkeli	138	» 7	» 4	2 650	4 860	51.6	40.0	1.8	4.3	25.3	29.7	9.2	14.6	2.3	4.3	61	209
Jomala (clay soil)	138	» 9	» 15	2 560	3 520	23.4	12.4	3.6	9.4	22.5	24.0	7.3	11.5	1.6	2.8	41	99
Fiskars	154	» 4	» 9	2 430	4 400	18.6	19.0	4.6	8.1	26.3	30.4	8.6	13.2	2.3	4.0	56	176
Nokia I	142	» 10	» 5	2 400	3 200	20.0	24.0	3.6	4.0	26.1	33.3	7.7	17.0	2.0	5.7	48	182
Ruukki	133	» 7	» 7	2 290	2 860	17.0	17.6	4.7	5.7	25.1	29.2	7.8	13.9	2.0	4.1	46	117
Pälkäne	145	» 14	» 8	2 250	3 030	27.0	24.2	2.5	3.8	27.4	28.1	8.3	15.8	2.3	4.4	52	133
Leteensuo ..	146	» 14	» 8	2 100	6 460	33.8	26.0	2.5	8.7	22.5	22.0	5.3	9.6	1.2	2.1	25	136
Hanko	147	» 15	» 4	2 000	3 000	20.4	20.0	3.4	4.5	29.9	35.5	6.0	14.9	1.8	5.3	36	159
Kangasala ..	145	» 19	» 6	1 900	2 460	22.2	16.8	3.0	5.1	23.5	28.0	7.0	10.9	1.6	3.1	30	76
Vihti	138	» 7	» 2	1 850	2 850	10.2	5.4	5.4	15.8	23.2	23.2	8.0	9.6	1.9	2.2	35	63
Average	142			3 530	4 480	35.6	31.7	3.7	6.1	25.6	28.0	7.5	12.8	1.9	3.7	68	158

[1]) Not included in the average.

The yield of roots from first year stands varied on different plantings in 1943—47 from 1 000 to 7 890 kg. per ha., averaging 1 870—3 530 kg. per ha. The yield of rubber obtained from first year stands varied correspondingly from 10 to 142 kg. per ha., averaging 31—68 kg. per ha. Variations are even greater for yields obtained from second year stands, owing to different carry-over in different winters (cp. p. 48 and Table 17).

The yield of roots from second year stands varied on different plantings from 70 to 7 620 kg. per ha. Average yield of roots was in different years 1 210—4 480 kg. per ha. The yield of rubber varied for second year stands from 2 to 231 kg. per ha., average yields ranging from 31 to 158 kg. per ha.

Rubber content of the roots was for first year plants 1.1—2.4 % of fresh weight and 4.5—9.4 % of dry matter. For second year roots rubber content was almost doubled, being 1.3—5.7 % of the fresh weight and 6.2—17.0 % of the dry matter of the roots. Fluctuations of rubber content in the second year plants are due to different amounts of the old cortical tissue in roots. Though attempts were made to harvest the roots at a time in the middle of summer when the old cortical tissue had not been sloughed off yet, and the new tissue was already formed, results of analyses and observations made after harvesting show that in some cases harvesting was done too early, in others too late. The rubber content of roots is considerably increased by the old cortical tissue, for rubber does not disintegrate easily and is left on the root even after disintegration of other organic substances.

The increase in the rubber content and the new growth of roots in the second year were able to compensate for winter losses and to double the yield of rubber every year, with the exception of the first year of investigations when only average 28.4 % of the plants were carried over to the second year (Table 24). A survey of the average root weights in first and second year plants shows that the new growth during the second year was able to double, sometimes more than double, the weight of the roots. In very dense stands, e. g. at Tikkurila in the years 1945—46 and 1946—47 hardly any new growth was observed. The most important factor limiting new growth in a dense stand was naturally lack of space, but also drought and lack of nutrients may be responsible.

In 1947 the yield of rubber per ha. from second year stands was on the average 5 times the yield obtained in the first year of experiments, namely 158 kg. per ha. Four experimental areas produced over 200 kg. of rubber per ha. These plantings were located at Tikkurila, Ylistaro, Mouhijärvi, and Mikkeli.

Comparisons show that yields obtained in Finland are similar to those obtained in U. S. S. R. in 1938 and 1939, according to Mynbaev's (cp. p. 10) information. Altukhov's (1, ref. 133, p. 11) information

Table 28. Averages of the yields of first and second year kok-saghyz in Finland in the years 1943—1947.

Year	Number of experimental fields	Growth period (days)	Yield of roots kg. per ha.		Number of plants per row meter		Average root weight g.		Dry matter %		Rubber					
											in dry matter %		in fresh weight %		kg. per ha.	
		1-year-old	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old
1943—44	14	140	2 280	1 210	9.6	2.7	8.6	16.4	24.4	22.6	6.7	11.2	1.7	2.6	38	31
1944—45	20	146	1 870	2 070	10.2	5.6	6.7	12.8	24.1	27.4	6.8	11.2	1.6	3.1	31	62
1945—46	9	134	3 250	3 340	20.3	15.9	6.1	8.8	26.0	26.8	5.5	12.5	1.4	3.4	47	112
1946—47	18	143	3 530	4 480	35.6	31.7	3.7	6.1	25.6	28.0	7.5	12.8	1.9	3.7	68	158

again indicates that up to 1937 the yields of rubber in U. S. S. R. were considerably lower than the yields obtained in Finland in 1943—47. He reports only 20 kg. per ha. as the average yield of rubber during many years. In the 1940's, first year kok-saghyz stands on peat soils, however, have produced very high yields, about twice the best yields obtained in Finland (112, p. 43).

When the yields obtained in Finland are compared to those obtained in U. S. S. R. consideration must be given to the fact that in Finland the yields were obtained from small experimental areas (1—10 ares), whereas in U. S. S. R. large areas were sown to kok-saghyz.

Tables 24—27 indicate that rubber content of fresh roots was seldom higher than 2 % in Finland, though this is usual in U. S. S. R. test fields (cp. p. 10). It is evident that the short growing period in Finland interrupts the development of kok-saghyz and the increase in rubber content at the end of growing season (cp. 73, p. 309; 99, p. 313).

In U. S. A., Canada, and Sweden, where the greatest number of tests have been conducted, U. S. S. R. excluded, yields have been similar to those in Finland (cp. pp. 8—15).

Tests with seedlings.

Establishment of kok-saghyz stands from seedlings was tested only at Tikkurila in 1944—46. Seeds were sown at the end of April in boxes in a laboratory. At 14—18° C germination occurred in 3—10 days. Seedlings were taken from boxes and planted in the field in single rows, when they were about 1 month old. By that time seedlings had developed a few 1—2 cm. long leaves besides cotyledons. Planting was done after rain. Rows were spaced 30—45 cm., and seedlings 5—10 cm. apart. Rooting was slow, but occurred in 90—100 % of the seedlings, though no irrigation was given after planting. New leaves did not begin to grow until 3—4 weeks after planting. Immediately after planting seedlings turned reddish, and the reddish colour disappeared only after development of roots. Table 29 gives the results for some seedling cultivations on sand soil at Tikkurila.

As Table 29 shows the yield of roots was 3 000—5 000 kg. per ha, and the yield of rubber 52—102 kg. per ha. Comparison to field sowings at the same locality (Tables 25 and 26) shows no considerable differences between these two types of stands with regard to yield. Field-sown stands, however, were nearly three times as dense as seedling plantings. In 1946 the yield of rubber obtained from seedling stands was only about one third of the yield obtained from field-sown stands in the same area. But growing season for field-sown stands was 18 days longer and density

Table 29. Yields from first year kok-saghyz stands planted with seedlings at Tikkurila in 1944—1946.

Date of planting	Date of harvesting	Yield of roots kg. per ha.	Row space cm.	Number of plants per row meter	Average root weight g.	Rubber		
						in dry matter %	in fresh weight %	kg. per ha.
June 1 1944	Oct. 25 1944	4 100	30	9.9	12.5	7.7	2.1	84
May 17 1945	» 12 1945	4 440	40	14.0	12.7	7.2	1.9	84
June 5 »	» 25 »	4 460	40	14.3	12.4	5.9	1.5	67
May 22 »	» 28 »	5 120	40	17.0	12.0	8.2	2.0	102
» 17 »	» 28 »	3 170	40	8.8	14.5	7.4	2.0	63
June 6 1946	» 8 1946	3 040	40	18.0	6.0	6.4	1.7	52

about 5 times the density in seedling stands (see Table 27). Results of the dates of sowing and the dates of harvesting experiments (p. 78 and p. 83) indicate, however, that even if the growth period of seedling stands had been as long or longer than that of field-sown stands, seedling stands could not have produced so high yields as to compete with the yield of rubber obtained from a dense field-sown stand (40—95 plants per row meter).

For stands established early in spring from seedlings the rubber content of roots was in autumn 10—20 % higher than for early field sowings at the same time in autumn. This was naturally due to the longer growth period of seedling stands (cp. p. 81).

Experimental fields established by planting seedlings were also carried over to the second year. During winter and early spring 10—15 % of the plants were destroyed. Destruction was chiefly caused by *Sclerotinia* sp. which attacked the roots at the crown. Root breaks due to frost heaving occurred also. On sand soil, and most experimental fields were located on sand soil, almost 100 % of seed-sown kok-saghyz was carried over winter in dense stands (40—95 plants per row meter). During the second summer very little new growth occurred in the roots of seedling stands, and yield of roots per ha. was reduced owing to winter losses.

Though experiments with seedlings were only carried out at Tikkurila in 1944—46 in small areas, the results indicate that kok-saghyz stands established by field sowing and with a density of 40—95 plants per row meter give higher yields of rubber than seedling stands. No experiments were made with the group planting used in U. S. S. R. (cp. 3, p. 30), but as kok-saghyz thrives in dense stands, it is possible, that planting of seedling groups would result in higher yields than planting of single seedlings.

Though the first hand weedings and harrowings are unnecessary, if kok-saghyz stands are established from seedlings, this method must be considered inadvisable, for planting requires plenty of labour. Besides, establishment of box sowings and their management meet with greater difficulties than field sowing.

Establishment of kok-saghyz stands from seedlings is a relatively little used method, for only a few mentions of it occur in the literature on kok-saghyz (6, p. 275; 133, p. 93).

Vegetative propagation.

On the basis of the investigations conducted by LYSENKO (65; 66; 69), FILIPPOV (37), and MYNBAEV (87), kok-saghyz is considered suitable for vegetative propagation. This method is based on the dormant period of the plant and on the capacity of root cuttings to resume growth quickly.

LYSENKO (65; 66) gave the first instructions for this method in 1941. These instructions advised to plant the callused root cuttings early in *spring*. Cuttings were taken from roots carried over winter and lifted from the soil immediately after thawing. The cuttings were then callused in sand for 12 days, and thereafter planted in the field.

In 1945 LYSENKO (69) published new instructions for vegetative propagation. According to these new instructions the best time for planting was *autumn*, at the time when autumn crops were sown.

When kok-saghyz is propagated vegetatively according to LYSENKO, cuttings are taken from first year roots. If roots are 0.5 cm. or thicker, cuttings 1.5 cm. in length are taken; if roots are thinner cuttings must be 3—4 cm. in length. Average weight of cuttings must not be lower than 0.25 g., or higher than 0.50 g. Cutting must be done by means of a very sharp knife in order to prevent excessive damage to roots. After 3—5 hours, at the latest, cuttings must be mixed with good garden mould using about equal amounts of each. Moisture of the mould must be such as to be favourable for seed germination. For the period of callusing mould and cuttings are covered with straw mats. Every fifth day the germination beds must be stirred by means of a spade to secure aeration. At 15—20° C adventitious buds are formed on section surfaces of the roots in 10—15 days.

After appearance of adventitious buds the cuttings can be planted. The best time for planting is autumn, at the time when autumn crops are sown. Cuttings are planted in well-prepared soil, divided in 60 cm. plots. A small pit is made at every corner and 15—20 cuttings together with the mould are put in it and covered lightly at the depth of 1—1.5 cm. Finally the pit is filled with compost mould. 150 kg. of roots and 8—9 tons of compost mould per ha. are required for this method. If planting is done without compost mould, which is not recommended, cuttings must be covered to the depth of 2.5 cm. It is important that buds should have developed, especially if planting occurs at a late date. But planting must not be done too early, either. MYNBAEV (87) says that 1.5—2 cm. of root should be cut off at the crown, for if crowns are used as cuttings, they only develop leaves and are susceptible to rotting. LYSENKO's instructions from 1945 advised to plant the crown cuttings, cut lengthways, in a different place, for they develop more quickly than ordinary root cuttings. Instructions were given for spring planting.

As advantages of vegetative propagation are mentioned:

1) Average size of roots is 3—5 times larger than for seed sowing.

2) Rubber content of roots is higher (69).

3) Demand for labour at the time of harvesting is smaller, as owing to the large size of roots their number per ha. is considerably lower than in seed-grown stands (cp. 31, p. 28; 69).

The large demand for labour at time of planting must be regarded as the greatest drawback of vegetative propagation.

In Finland vegetative propagation was chiefly tested at Tikkurila.

Experimental plantings with root cuttings were established according to LYSENKO's instructions (65; 66; 69). In 1944—46 root cuttings were planted early in spring. Roots were lifted from the soil immediately after thawing, before the rosette had started growing. Lifting of roots occurred in Finland in these years during the last week of April, or at the beginning of May. Roots with diameter of at least 0.5—1 cm. at the crown were selected and cut into fragments 1—1.5 cm. long. The fragments were then callused at 14—15° C in a moist 10—15 cm. deep sand layer. Every second day or so the sand was stirred by hand to secure good aeration.

In the spring of 1944 root cuttings were taken on April 28. In 4—5 days fine roots, about 2—3 mm. in length, were observed on them. These disappeared after a few days. After 12 days adventitious buds were observed on the cross section surfaces of the cuttings (Fig. 22). Excessive moisture and lack of air were very injurious to callused root cuttings. Excessive moisture turned the white buds transparent and the cutting began to rot. Moisture conditions were best, if the sand was easily detached from hands, but remained grainy when stirred. Germination occurred in the same way in 1945 and 1946.

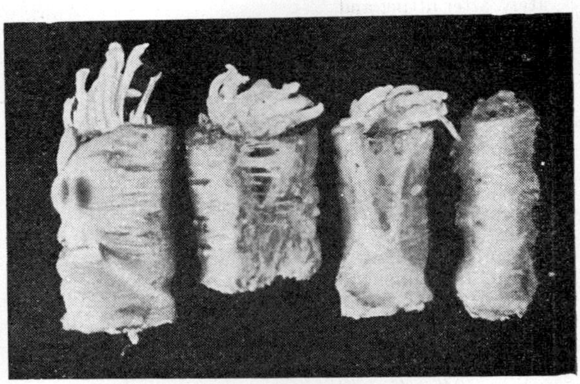


Figure 22. Root cuttings callused for 14 days and kept in mould for 4 days. Pale adventitious buds developed on the cuttings. Photograph taken May 16 1944. (Orig.)

In 1944 cuttings taken from roots kept in sand in a cellar over winter were also used. Place of storage was a potato cellar without any refrigerating facilities. Until the end of November temperature in the cellar was about 10° C. After that the temperature in the cellar was gradually lowered by frosty nights. Evidently the temperature was too high during storage, for already at the beginning of March roots developed small rosettes. By the end of April, when cut for callusing, the roots had become soft. This was evidently due to respiration losses and evaporation

Table 30. Results obtained by vegetative propagation at Tikkurila in the years 1944—1947.

Origin of the root cuttings	Percentage of cal used cuttings after 14 days	Date of planting in the field	Percentage of cuttings rooted in the eld	Average root weight g.	Yield of roots kg. per ha. (in Oct.)	Rubber in October		
						in dry matter %	in fresh weight %	kg. per ha.
		Spring plantings.						
Year 1944.								
Root cuttings stored in a cellar	20—30	May 15	0—3	—	~500	—	—	—
Root cuttings lifted in spring.	79—94	» 15	2—10	22—80	500	6.8—9.9	1.8—2.4	—
Crown cuttings. Stored 14 days in a refrigerator before planting.	—	» 15	20—56	15—50	~1 000	—	—	—
Year 1945.								
Root cuttings lifted in spring.	86—98	May 2	4—22	15—70	~500	—	—	—
Crown cuttings. Planted in the field immediately after lifting and topping.	—	» 2	95—100	19	7 870	7.8	1.9	150
Year 1946.								
Root cuttings from roots planted from cuttings in previous year and lifted in spring.	93—100	» 9	7—37	10—46	~500	7.7	2.0	—
Root cuttings lifted in spring.	84—98	» 9	5—11	17—42	~500	—	—	—
Crown cuttings. Planted in the field immediately after lifting and topping.	—	April 24	95—100	10—30	6 070	11.9	2.9	176
		Autumn plantings.						
Year 1946—47.								
Second year root cuttings. Lifted Aug. 22 1946	93	Sept. 5	13	32	1 460	10.7	3.0	44
	93	» 10	11	28	1 590	9.1	2.7	43
Root cuttings from roots planted from cuttings in previous year and lifted Sept. 6 1946	85	» 24	5—6	42	1 090	7.9	2.4	26
First year root cuttings. Lifted Aug. 6 1946	85	» 24	2—3	22	490	8.6	2.4	12

of water during storage. Formation of the rosette during storage also weakened the roots, and callusing losses were considerable.

Crown cuttings, whether taken from roots lifted in spring, or from roots stored in a cellar, were kept in a refrigerator at 2° C for about 2 weeks and planted in 1944 at the same time as the callused root cuttings. In 1945 and 1946 crown cuttings were planted on the same day as roots were lifted for vegetative propagation. In 1946 part of the root cuttings were taken from plants which had been propagated vegetatively in the previous year. According to LYSENKO (66; 69), such plants should attain larger size than plants grown from root cuttings taken from seed-grown plants.

When LYSENKO in 1945 published new instructions for vegetative propagation of kok-saghyz recommending autumn planting, a test field was established at Tikkurila in September 1946.

Spring plantings were done in 1—2 cm. deep furrows which were then covered with mould. Furrows were spaced 40 cm. apart. The average rate of planting was 10 cuttings per row meter. At *autumn planting* groups of cuttings were planted together with the germination mould. Space between groups was 60 × 60 cm. and every group consisted of 20—25 cuttings. Cuttings were covered with good compost mould.

Results of the experiments with vegetative propagation are given in Table 30. Groups of cuttings resulted in different rate of germination and rooting. Range of the results is reported, if cuttings were not taken from the same stand, otherwise averages of the different groups (2—5 groups) are given. 1 520 cuttings were planted in 1944, 1 030 in 1945, 2 625 in 1946, and 1 460 in 1947.

Material for the investigations of vegetative propagation was relatively scarce. Table 30 only indicates that at Tikkurila in 1944—47 stands established by vegetative propagation from root cuttings either in spring or in autumn were not able to compete with the yields obtained from field sowings, owing to great losses of root cuttings after planting (Fig. 23).

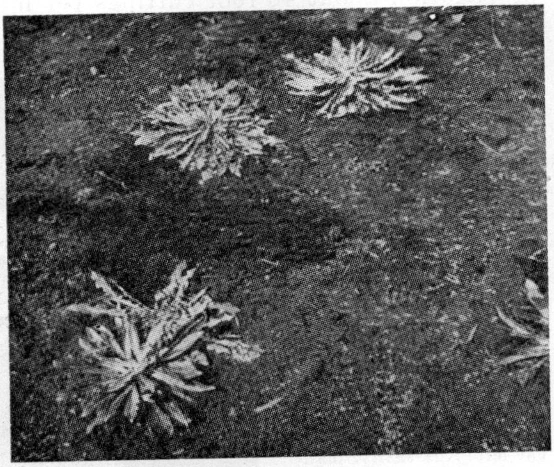


Figure 23. Thin kok-saghyz stand at Tikkurila Aug. 14 1944 planted from root cuttings early in the spring. Photograph by O. Valle.

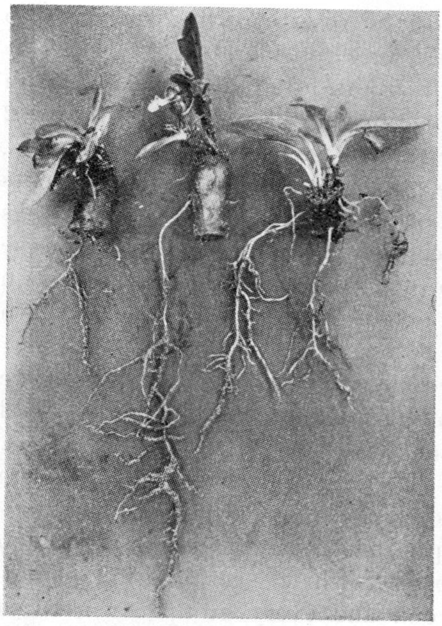


Figure 24. Cuttings from second year plants planted in the autumn of 1946. Roots grown in the spring, rosettes formed in the autumn. Samples taken and photographed May 20 1947. (Orig.)

Only one yield from a stand established by vegetative propagation was equal to the yields per ha. obtained from plants from seed. This occurred in the autumn of 1947, when the plants from second year root cuttings were harvested. Root cuttings of second year plants probably rooted better (Fig. 24) than those of first year plants (Fig. 25), because they were in dormancy at the time of lifting (cp. p. 50). Usually first year roots do not enter dormancy in Finland because of the short growth period, or dormancy occurs so late in autumn that planting of root cuttings is no longer possible. The above-mentioned stand yielded 44 kg. of rubber per ha. The density of stand was 5 plants per 1 m². In order to secure an equal yield from plants from seed the density of the stand must be 40 plants per m². However, consideration must be given to the fact that before a stand with 5 plants per 1 m² was established by vegetative propagation about 40 root cuttings per m² were planted.

Figure 25. (On the right) Root cuttings from first year plants which have been in the field for more than a month June 20 1944. Root on the right has started rotting. (On the left) Kok-saghyz plant from crown cutting, after a month from planting. (Orig.)

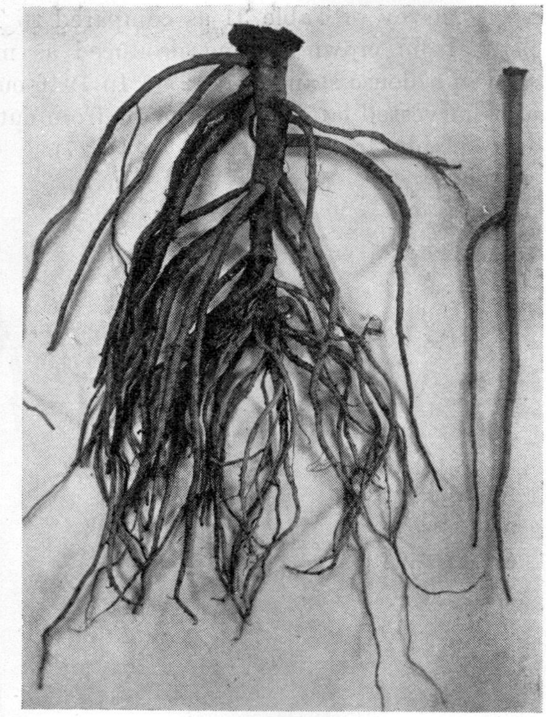


Figure 26. (On the left) Root grown from a root cutting, planted May 26, harvested Oct. 16 1944. Length of root 30 cm., weight 80 g. Plant was of the type in Figure 17. (On the right) Root of the same age grown from seed. Length 25 cm., weight 5 g. (Orig.)

Table 30 indicates that the roots of vegetatively propagated plants were much larger than those of seed-grown plants (Fig. 26), and rubber content was slightly higher than for plants from seed of about the same age. But most of the root cuttings were destroyed after planting in the field, and owing to thin stands the final yield per hectare was low.

The results achieved by vegetative propagation have not been negative in Finland alone. Also the experiments conducted in U. S. A., Germany, and Sweden have almost all been failures (43; 72; 85; 133, pp. 89—93). For U. S. S. R. MOLOTKOVSKY (85) reports failure of experiments with root cuttings conducted in southern Kazakhtan. About 5 to 10 days after planting the cuttings were destroyed. In Sweden, in southern Halland this method was tested in 1944 in an area of 25 ares with root cuttings imported from Poland, but the planting was a complete failure (43).

Though root cuttings usually resulted in very poor stands in the experiments at Tikkurila, about 100 % of the crown cuttings survived if planted in the field immediately after topping in spring. Table 31 reports the yields obtained from stands established from crown cuttings in 1945—46.

Table 31. Yields of stands established from crown cuttings at Tikkurila in 1945—1946.

Year	Date of planting	Date of harvesting	Row space cm.	Yield of roots kg. per ha.	Number of plants per row meter	Average root weight g.	Rubber		
							in dry matter %	in fresh weight %	kg. per ha.
1945	May 2	Oct. 25	30	7 870	14.0	16.9	7.8	1.9	150
1946	April 24	Nov. 8	35	6 070	21.3	10.0	11.9	2.9	176

A survey of Table 31 as compared to Table 26 shows that in 1945 a plant from crown cutting produced as much rubber as 3 plants from seed in a dense stand (Fig. 27). In 1946 cuttings were planted very early and harvested late, and one plant from cutting produced as much rubber as 6 plants from seed (cp. Table 27).

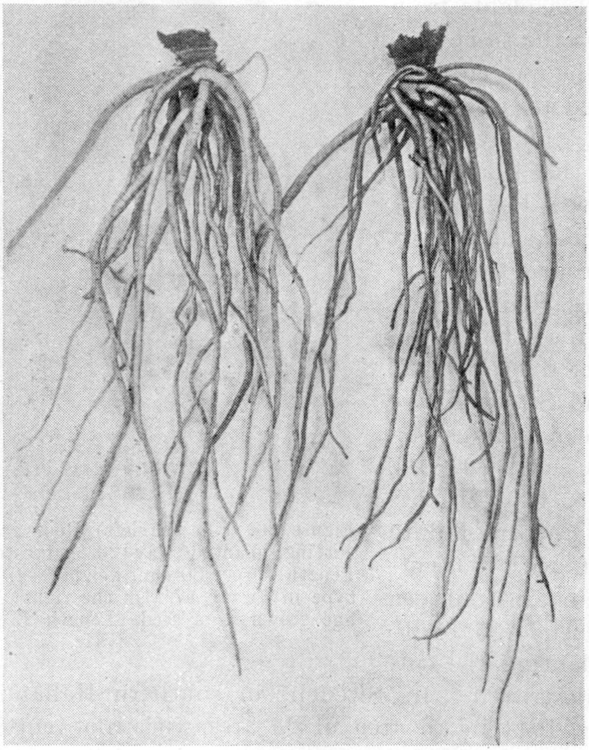


Figure 27. Roots developed from crown cuttings. Cuttings planted April 25 1945, harvested and photographed Sept. 25 1945. Yield of roots 7 870 kg. per ha., yield of rubber 150 kg. per ha. (Orig.)

If plantings were to be established by this method, a dense stand, e. g. 60—70 plants per row meter (5—6 kg. of seed per ha.) should be sown early in spring. This stand should be harvested in the following spring, which would be advisable with regard to the quality of rubber (73, p. 308; 18). When the lifted roots are topped 0.5—1 cm. of root should be cut together with leaves. According to this method, a kok-saghyz stand should be established every other year from seed and every other year from crown cuttings. The latter stands should be harvested in autumn, as they do not winter so successfully as dense field sowings.

This method can only be used on sand and finesand soils drying quickly in spring. Areas with long period of snow cover followed by rapid thawing are well suited for this method of cultivation. Planted crown cuttings were not sensitive to night frosts, and they even survived slight frost heaving of the soil. WHALEY and BOWEN in U. S. A. (133, p. 92), and MOLOTKOVSKY in U. S. S. R. (85) also report good stands from crown cuttings as compared to root cuttings. Literature on kok-saghyz, however, does not make any mention of this method being used except for experimental purposes.

Tests arranged in order to determine the cause of cutting losses in spring and in autumn showed that great susceptibility to excessive moisture was one of the reasons. This was clearly seen in pot experiments conducted in laboratory. Callused cuttings were planted in ordinary flower pots which were placed on a stand with low sides. This could be filled with water. Surface irrigation was not given, and cuttings received all water capillarily, and had no connection with free water. Only so much water was poured into the receptacle as could be absorbed by the mould in pots at a time. Irrigation was given every second or every third day.

Pot experiments also showed that root cuttings were resistant to drought. Cuttings which had developed 7 or 8 leaves were not killed though no irrigation was given for one week. Part of the leaves turned yellow and died, but the centre of the rosette survived and new leaves developed as soon as the moisture conditions were favourable to growth. On the other hand, abundant irrigation given both as sub-irrigation and as surface irrigation resulted in complete destruction of especially the young cuttings in 4—5 days.

No special pathogenic organism causing the rotting of roots was found in the investigations of the killed root cuttings, conducted at Agricultural Research Institute, Department of Plant Diseases. Rotting was caused by bacteria in the soil. The species of these bacteria were not determined. Some fungi of the species *Fusarium*, *Botrytis*, and *Sclerotinia* were also found, but none of them could be proved to have been the primary cause of destruction.

Suffocation caused by excessive moisture may thus be considered responsible for the destruction of root cuttings. Germinated root cuttings would need at least 3 or 4 weeks' rainless period in the field in order to develop roots and rosettes of adequate size. Crown cuttings are more resistant to excessive moisture, probably because they are able to evaporate surplus water through their leaves.

Evidently only few root cuttings develop quickly enough to escape destruction.

It is probable that in unimproved stands some plants are more suited to vegetative propagation than others. If attention were to be paid to this fact in breeding work, use of vegetative propagation might be increased. But as long as root cuttings survive in the field as poorly and unevenly as many experiments have shown, vegetative propagation is of no practical importance at the establishment of kok-saghyz stands.

Effect of vernalization and date of sowing.

Effect of vernalization on the germination and emergence of seed has been already discussed (pp. 35—45). In connection with the dates of sowing experiments, investigations were conducted at Tikkurila in order to determine the effect of vernalization on the yield of roots and rubber from early and late sowings. The first sowing was done very early in spring, and two more sowings were done later at about 2 weeks' intervals.

Up to 1940 two thirds of the sowings in U. S. S. R. were autumn sowings (133, p. 53). After that spring sowings have become more common. After many experiments AVSAREGOV (5, p. 54) reached the conclusion that early spring sowing with vernalized seed is better than autumn sowing. Opinions as to the value of vernalization have differed. WHALEY and BOWEN (133, pp. 42—43) mention that according to experiments in U. S. A. vernalization is of no importance under favourable moisture conditions. It is also claimed that German growers did not find any effect by vernalization on the yields obtained from fields in Poland and Ukraine (31, p. 33). In Sweden the effect of vernalization proved favourable (6, p. 273).

Only one dates of sowing experiment was conducted at Tikkurila in 1944 with the seed imported from Germany in 1942. In 1946—47 native seed was used in all tests. Period of vernalization was in 1946 20 days, in 1947 28 days for all sowings. In laboratory tests vernalization increased the germinability of the seed with 30 %. Results of vernalization and dates of sowing experiments are given in Table 32. Rate of sowing indicates the amount of germinable seed used per ha. The higher germinability of vernalized seed as compared to that of untreated seed was taken into consideration.

Comparisons between the effects of the date of sowing on the yield of rubber in different years, if unvernalized seed was used, indicate that the earliest sowing usually resulted in the highest yield of rubber (Fig. 30). In 1947 no distinct difference between the yields from different sowings was observed, but rubber content was higher for the first two sowings than for the third sowing. The results of 1947 were influenced by long rainless periods in spring which retarded the development of

Table 32. Results of vernalization and dates of sowing experiments at Tikkurila in 1944, 1946, 1947.

Date of sowing and treatment	Date of harvesting	Yield of roots		Rubber				Density	
		kg. per ha.	rel. number	in dry matter %	in fresh weight %	kg. per ha.	rel. number	plants per row meter	rel. number
1944.									
Untreated. Rate of sowing 3.0 kg. per ha.									
May 14	Oct. 25	**4 710**	**100**	7.9	1.9	**89**	**100**	33 (Fig. 28)	
» 29	»	4 390	93	7.7	1.9	83	93	30	
June 13	»	3 640	77	7.2	1.9	69	78	28 (Fig. 29)	
F = 64.3***; minimum significant difference for yield of roots 269 kg.; m % 1.6									
1946.									
Vernalized. Rate of sowing 2.4 kg. per ha.									
May 11	Oct. 8	**5 240**	**100**	6.6	1.7	**89**	**100**	**68**	**100**
» 21	»	3 990	76	6.5	1.7	68	76	90	132
June 4	»	3 270	62	6.3	1.6	52	58	62	91
Untreated. Rate of sowing 2.5 kg. per ha.									
May 11	Oct. 8	4 190	80	6.5	1.7	71	80	55	81
» 21	»	3 500	67	6.3	1.6	56	63	66	97
June 4	»	2 520	68	5.9	1.6	40	45	28	41
F = 25.2*; minimum significant difference for yield of roots 449 kg.; m % 3.7									
1947.									
Vernalized. Rate of sowing 6.2 kg. per ha.									
May 9	Oct. 10	**4 910**	**100**	7.6	2.2	**108**	**100**	**80**	**100**
» 23	»	4 540	92	7.2	2.2	100	92	96	120
June 6	»	4 610	94	6.5	2.0	92	85	134	168
Untreated. Rate of sowing 6.1 kg. per ha.									
May 9	Oct. 7	3 240	66	7.6	2.2	71	66	43	54
» 23	»	3 521	72	7.0	2.2	77	72	65	81
June 6	»	3 490	71	6.1	1.8	63	58	55	69
F = 3.7 *; minimum significant difference for yield of roots 1 119 kg.; m % 9.2									

kok-saghyz and prevented the growth of the earlier sowings. The highest increase in yield occurred in 1946 when early sowing yielded almost twice as much rubber as the plants sown about a month later.

Though results from dates of sowing experiments are available only for three years they seem to indicate that in Finland it is best to sow kok-saghyz at the earliest possible date, even though exceptional weather conditions may reduce the advantages of an early sowing. In 1944, 1946, and 1947 the best time for sowing was in southern Finland the second week of May.

Experiments with vernalized seed conducted in 1946 and 1947 in connection with the dates of sowing experiments showed that vernaliza-

Figure 28. Kok-saghyz stand of first sowing at Tikkurila in mid-August.

Figure 29. Third sowing in mid-August sown a month later than the first sowing in Figure 28.
Photographs by O. Valle.

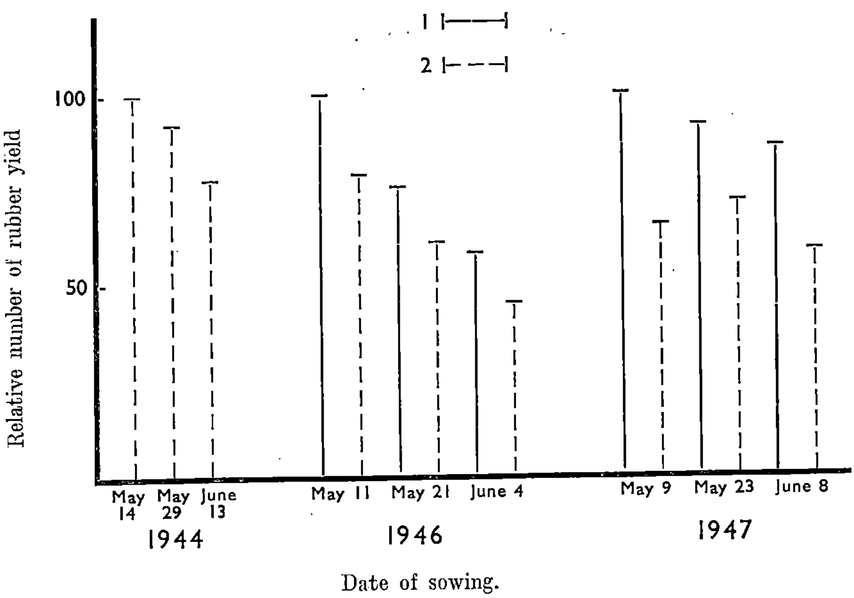


Figure 30. Effect of the date of sowing and vernalization on the yield of rubber. 1 = vernalized, 2 = untreated. Rubber yield of first (vernalized) sowing = 100.

tion is an important factor with regard to increases in the yields of roots and rubber. The increases in yield were highest (20—30 %) for early sowings (Fig. 30).

Early sowings with vernalized seed in 1946 and 1947 were usually thinner than later sowings, but their yield of roots and rubber was so much increased due to longer growth period (2 weeks) as to render an early sowing with vernalized seed most advisable.

A survey of the density of stands sown at different dates (Fig. 31) shows that densest stands for the same date of sowing were always secured with vernalized seed.

Vernalized seed resulted up to 2.5 times as dense a stand (third sowing of 1947) as untreated seed. Figure 31 indicates that the date of sowing was not of decisive importance with regard to density. Weather conditions prevalent immediately after sowing were evidently the decisive factor influencing emergence. E. g. in 1947 a shower of rain occurred immediately after sowing on the day of the third experiment. Soil was well moistened. For vernalized seed this moisture was sufficient to secure quick germination, but untreated seed could not take advantage of a rain occurring so soon after sowing. As no rains occurred during the next few days after sowing, vernalized seed resulted in much quicker development and denser stand than untreated seed.

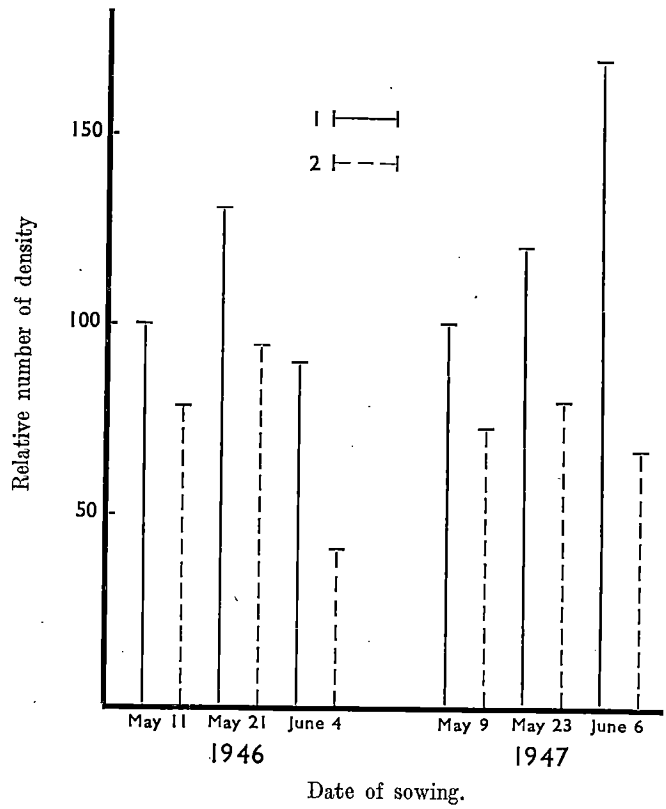


Figure 31. Effect of the date of sowing and vernalization on the density of kok-saghyz stands. 1 = vernalized, 2 = untreated. Density of first vernalized sowing = 100.

Comparative observations between vernalized and untreated stands in the springs of 1947 and 1948 indicated better wintering and quicker start of growth for stands sown with vernalized seed. Further and more detailed investigations, however, will be necessary to determine the exact cause for the better wintering of vernalized stands. It is evident that at least in the reported experiments the density of vernalized stands (cp. p. 46) contributed to their good survival.

Investigations with regard to the effect of vernalization and date of sowing on the yield of roots and rubber conducted at Tikkurila indicate that in order to secure high yields of roots and rubber seed should be vernalized, and sown early in spring. As emergence of vernalized seed is better than that of untreated seed, less seed is needed for sowing.

Effect of date of harvesting.

Russian investigators suggest that with regard to the yield of rubber first year roots should be harvested at the latest possible date in autumn (18; 73; 99). Investigations in Sweden have also confirmed a considerable increase in the rubber content of roots at the end of the first growing season (6, p. 277).

MASHTAKOV (73), NICHIPOROVICH and BOUROVAYA (99) observed that with an increase in rubber at the end of the growing season also the quality of rubber improves. Rubber is usually the better, the higher its degree of polymerization. Polymerization of rubber takes place in the root of kok-saghyz towards the end of the growing season, and it continues even after growth ceases. Therefore the above-mentioned investigators think that with regard to the quality of rubber it is best to harvest first year roots in the spring of the second growing season.

The investigations of MYNBAEV (87, ref. 133, p. 124) indicate a slight reduction in rubber content of roots, if harvesting occurs too late in autumn. In his opinion the best time for harvesting is the time in autumn when growth of kok-saghyz has entirely ceased. In any case it is advisable to harvest the roots before the autumn rains set in (147, p. 26).

Literature on kok-saghyz seems to indicate that kok-saghyz roots are generally harvested in the autumn of the first year. ALTUKHOV (3, p. 51) recommends that harvesting of the roots should be carried out in the next summer, if root weight is not over 0.5—1.0 g. In U. S. S. R. kok-saghyz has also been cultivated as a biennial plant (cp. pp.9—10).

ALTUKHOV's instructions recommend the middle of summer as the best time for harvesting roots of second year stands. By that time seed is mature, and the rubber in the old cortical tissue has not been sloughed off yet. In order to determine the proper time for harvesting, roots must be examined at the end of the period of seed formation by lifting them out of the soil and examining the stage of development of the new cortical tissue. If second year roots are not harvested in the middle of summer, the yield of rubber is considerably reduced, for new growth is not sufficient to compensate for the rubber lost with the sloughing-off of the old cortical tissue (3, p. 12; 142, p. 26). The Germans thought that second year roots should be harvested about a week after the main period of seed formation (31, p. 38).

In order to determine the best time of harvesting for Finland dates of harvesting experiments were conducted at Tikkurila and some other localities in 1943—47. Attention was paid to the following items:

1. Determination of the best time of harvesting for first year stands in autumn.

2. Changes in the dry matter, rubber, and resin contents of the roots during the autumn of the first year and during the second growing season.

3. Yield of rubber and roots from first and second year stands at different dates.

In order to determine the best time for root harvesting in the autumn of the first year samples were taken at Tikkurila in 1944—46. Taking of samples and calculation of yields were conducted in the same manner as in experimental fields. An area with fairly uniform stand was selected, and crops from 4—5 row meter were harvested at different dates in autumn. When the exactness of the method of sampling was tested the proportion of standard error in the mean yield was found to be 2—3 %.

Stands used for sampling were established from seed, except in 1945 when samples were also taken from seedling stands.

The vigour of the stands at the time of harvesting was determined by weighing the rosettes taken at topping. Partly wilted leaves and bases of wilted leaves still attached to rosettes were included. The growth of the above-ground parts and the yield of roots are naturally largely dependent on the factors affecting the food supply of the plant. As these factors varied in different years and in different fields, the relation between the weight of rosettes and the weight of roots was determined. This ratio was called *weight relation index*. The higher the weight relation index was at the time of harvesting, the more vigorous was the growth of plants.

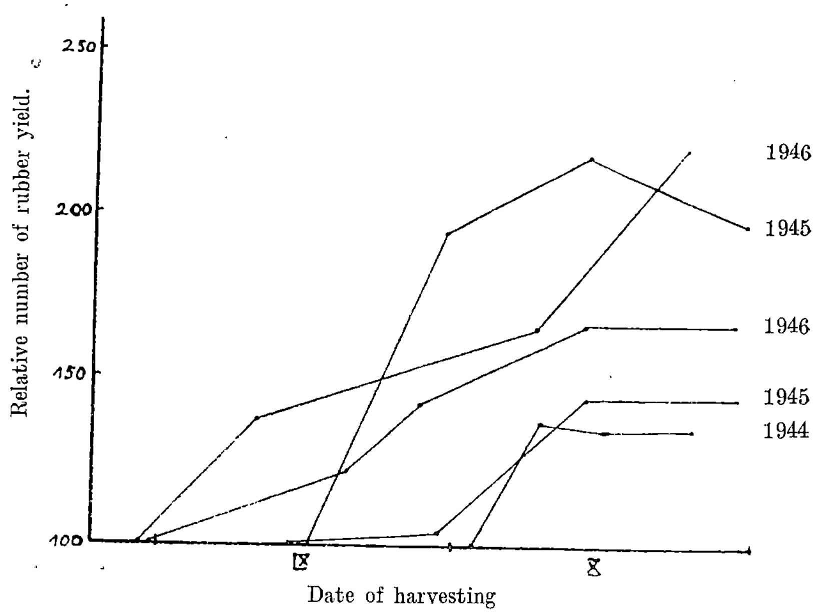


Figure 32. Yield of rubber from first year stands at different dates in autumn in the years 1944—1946, at Tikkurila. First harvesting = 100.

In 1944 harvesting was done at one-week intervals, in 1946 the interval was prolonged to 2 weeks in order to secure more distinct differences in the yields. In 1946 two harvestings were done at the end of August and the beginning of September, and two more a month later towards the middle of October. Results of these experiments are given in Table 33 and Figure 32.

Table 33. Results of the dates of harvesting experiments for first year kok-saghyz stands at Tikkurila in the years 1944—1946.

Date of sowing	Date of harvesting	Growth period (days)	Yield of roots kg. per ha.	Yield of roots rel. number	Rubber in dry matter %	Rubber in fresh weight %	Rubber kg. per ha.	Rubber rel. number	Yield of rosettes kg. per ha.	Weight relation index
1944										
May 14	Oct. 2	141	**4 050**	**100**	6.5	1.6	**65**	**100**	9 020	2.2
»	» 9	149	4 650	115	7.6	1.9	88	136	7 010	1.5
»	» 16	156	4 310	106	7.6	2.0	86	132	5 830	1.4
»	» 23	164	4 340	107	7.8	2.0	87	134	3 530	0.8
1945										
May 26	Sept. 13	110	**5 190**	**100**	5.2	1.4	**73**	**100**	16 880	3.3
»	» 27	124	5 810	112	5.1	1.3	76	104	9 060	1.6
»	Oct. 11	138	6 560	126	5.7	1.6	105	144	9 380	1.4
»	» 28	155	6 160	119	6.4	1.7	105	144	7 060	1.1
1945										
Planted										
May 17	Sept. 14	—	**2 910**	**100**	5.6	1.4	**41**	**100**	7 310	2.5
»	» 28	—	4 230	180	5.5	1.4	76	185	7 310	1.7
»	Oct. 12	—	4 440	187	7.2	1.9	89	217	7 380	1.7
»	» 28	—	4 040	173	7.1	2.0	81	198	4 110	1.0
1946										
May 11	Aug. 29	110	**3 110**	**100**	6.7	1.8	**56**	**100**	4 430	1.4
»	Sept. 10	122	4 060	131	7.2	1.9	77	138	5 450	1.3
»	Oct. 8	150	5 180	167	7.1	1.8	93	166	2 790	0.5
»	» 19	161	5 570	179	8.4	2.2	123	220	—	—
1946										
May 21	Aug. 31	102	**5 360**	**100**	6.2	1.6	**86**	**100**	12 860	2.4
»	Sept. 9	111	6 140	115	6.8	1.7	104	121	9 110	1.5
»	» 23	125	7 250	135	7.0	1.7	123	143	—	—
»	Oct. 12	144	7 890	147	7.1	1.8	142	165	6 070	0.8
»	» 28	160	7 360	137	7.9	1.9	140	163	—	—

A survey of the yields secured at different dates of harvesting shows an increase in the yield up to the middle of October, after which there was no increase in the yield of rubber per ha. After mid-October a sharp decrease was observed in the yield of the above-ground parts, too. Thus *increase in the yield of rubber stopped at about the same time as the growth of the plant ceased and growing season ended.* Only on the planting established

May 11 1946 considerable increase was observed after October 15. This is probably due to the exceptional weather conditions of 1946. In this year precipitation was very low in July and August, and the development of kok-saghyz was delayed. September was rainy and favourable for the growth of kok-saghyz. No late accumulation of rubber was observed in the other experimental field located in an area which had been irrigated during drought period (see Fig. 32, and Table 33).

Table 33 indicates some decrease in the yield of roots after mid-October in some cases. Rubber content of the dry matter of the roots, however, increased resulting in the same final yield per ha. This may be explained in the following way: when temperature falls below zero the moisture in the roots decreases, and concentration of cell sap makes the roots resistant to frost. Further fall of temperature prevents taking of nutrients and results in respiration losses. Thus the percentage of rubber in dry matter increases. Comparisons between the dry matter content of the roots in autumn and in the following spring clearly reveal the losses in dry matter which have occurred during winter and spring (Fig. 33, p. 88).

Comparisons were made between the results obtained in Finland and those obtained in U. S. S. R. and Sweden. In autumn increase in the rubber content of roots occurred at equal rate in all countries. MASHTAKOV (73, p. 309) reports an increase in the rubber content of roots from 5.7 % to 7.4 % within three weeks in October. In Sweden, an increase from 1.5 % to 2.25 % in the rubber content of roots was observed at Svalöf during October (6, p. 227). The results of the dates of harvesting experiments also confirm MASHTAKOV's (76) opinion that the synthesis of rubber is only possible during the growth period of the plant.

When the roots from first year stands were harvested at experimental localities in the autumns of 1943—46, the above-ground parts of the plants were also weighed in the same way as at Tikkurila in connection with the dates of harvesting experiments (cp. p. 82).

In Table 34 the weight relation index is compared to the rubber content of the dry matter of roots at time of harvesting. Results were divided into 2 groups according to whether the rubber content of the roots was exactly 6.0 %, or less or more than 6.0 %. The number of growth days of the stands is also given in Table 34.

Table 34 shows that in 15 cases out of 25 the rubber content of the dry matter of roots from first year stands did not rise over 6.0 % until after 140 or more growth days and after the rosettes were so wilted that the weight relation index was 2 or lower. In 6 cases out of the other 10 rubber content rose over 6.0 % already after 133—138 days.

Weight relation index was in 4 cases, namely at Ruukki and Pälkäne in 1943, and at Fiskars and Vihti in 1946, exceptionally high at time of harvesting though dry matter contained 7.3—8.6 % of rubber. An

Table 34. Rubber content of the dry matter of roots and weight relation index in first year stands at time of harvesting in the years 1943, 1945, and 1946.

Rubber content of dry matter of roots.

Rubber content over 6.0 %					
Locality	Date of sample	Growth period (days)	Rubber in dry matter of roots %	Yield of rosettes kg. per ha.	Weight relation index
1943					
Hartola ...	Oct. 10	151	8.9	4 330	1.9
Jomala ...	Nov. 6	183	8.3	2 110	1.9
Leteensuo .	Oct. 15	153	9.4	1 810	1.8
Pälkäne ..	» 2	137	8.0	14 560	4.8
Ruukki ...	» 1	134	7.3	12 800	3.5
Tammisto .	Nov. 5	149	6.3	3 000	1.2
1945					
Tikkurila [1]	Oct. 11	138	7.3	7 750	1.4
»	» 25	179	9.0	4 820	1.1
»	» 25	162	7.7	4 560	1.0
1946					
Fiskars ...	» 4	134	8.6	8 570	3.5
Hartola ..	» 5	137	8.7	3 310	0.8
Jomala a..	» 9	138	7.3	9 330	2.0
» b..	» 9	138	7.3	4 120	1.6
Kangasala.	» 19	145	7.0	1 420	0.8
Lahti	» 14	142	8.0	3 430	0.8
Maaninka .	» 8	140	7.5	4 800	1.1
Mikkeli ..	» 7	138	9.2	1 630	0.6
Mouhijärvi	» 15	143	9.4	6 070	1.2
Nokia	» 10	142	7.7	3 070	1.3
Pälkäne ..	» 14	145	8.3	2 830	1.3
Ruukki ..	» 7	133	7.8	2 860	1.2
Savio	» 13	145	6.9	2 610	0.6
Tikkurila .	» 12	144	7.1	6 070	0.9
» .	» 8	150	7.1	2 790	0.5
Vihti	» 7	138	8.0	4 160	2.2
Average		146	7.9	—	1.6 [2]

6.0 % or less than 6.0 %					
Locality	Date of sample	Growth period (days)	Rubber in dry matter of roots %	Yield of rosettes kg. per ha.	Weight relation index
1943					
Fiskars ...	Sept. 28	143	5.8	12 580	3.4
Lahti	Oct. 10	134	6.0	6 250	2.5
Maaninka .	» 1	137	5.7	9 260	3.7
Mouhijärvi	Sept. 10	113	5.4	14 030	5.6
Rovaniemi	Oct. 1	127	5.6	11 700	5.2
Savio	» 2	143	4.9	5 390	3.9
Tikkurila .	» 2	130	6.0	2 170	2.2
1945					
Fiskars ...	» 5	148	4.5	12 000	3.6
Hanko ...	» 2	133	5.4	13 140	3.7
Kangasala.	» 9	132	5.6	11 330	3.6
Maaninka .	» 4	138	5.8	8 000	2.1
Mikkeli ...	» 4	127	5.5	3 030	1.1
Nokia	» 3	126	4.7	4 330	3.1
Ruukki ..	» 3	128	4.7	4 380	2.8
Savio	» 1	124	4.8	15 330	5.1
Ylistaro ..	» 5	141	5.2	12 500	4.5
1946					
Hanko ...	Oct. 15	147	6.0	9 140	4.6
Leteensuo .	» 14	146	5.3	6 900	3.3
Ylistaro ..	» 15	143	5.8	13 000	2.3
Average		135	5.5	—	3.5 [2]

examination of growth conditions at these localities showed that kok-saghyz stands were located in fields which were in very good farming condition. It may be possible that growth conditions were particularly favourable for the development of above-ground parts and for rubber formation. It is probable that thin stands in 1943 and 1946 at Vihti increased the vigour of above-ground growth (cp. p. 55). An accurate explanation of this phenomenon, however, cannot be given in this study.

[1]) Native seed from 1944. Other stands in 1945 established from seed imported from Germany in 1942.
[2]) Variance ratio (F) = 33.5***.

Table 34 shows, in addition, that in 18 cases out of 19 weight relation index was higher than 2, when rubber content of the dry matter of roots was less than 6.0 %. The planting at Mikkeli in 1945 formed the only exception. Poor above-ground growth on this planting was probably due to some occasional factors unfavourable to the development of rosettes. Especially conspicuous is the low rubber content for the yield in 1945. This must be attributed to the poor viability of the seed (cp. p. 32). The stands from this seed would have required a much longer growing season than usual before the rubber content of the dry matter of roots would have reached the same level as in 1943 and in 1946. Results obtained at Tikkurila with seed of the same origin confirm this opinion. In the areas at Tikkurila the rubber content in the dry matter of roots was 9.0 % and 7.7 % after a growth period of 179 and 162 days, respectively. In 1944 native seed was used in the same area, and rubber content was 7.3 % already after 138 days.

The difference between the means of weight relation indices was tested by analysis of variance. Since the variance ratio F was 33.5***, the difference between the means must be said to be very significant.

A survey of Table 34 shows that for the plants with lower rubber content than 6.0 % the growth period was ten days shorter. But the length of growth period varied considerably, and it is not possible to determine the proper time for harvesting on the basis of growth days. Attention must also be paid to the stage of development of the plants which is indicated by weight relation index. With regard to the time of harvesting it may be observed that plants with 6.0 % or lower rubber content of roots were generally harvested at the end of September or the beginning of October, whereas the plants of the second group (rubber content over 6.0 %) were harvested during the second week of October, or later.

Comparison shows that the results given in Table 34 are similar to the results obtained at Tikkurila in the dates of harvesting experiments. In the experiments at Tikkurila in 1945 weight relation index fell down to 2 and lower already before rubber content was over 6.0 %, but number of growth days was not sufficient by that time. The results given in Tables 33 and 34 indicate that *the best yield of rubber from first year stands was secured if roots were harvested after a growth period of 140 days and at the time when the weight relation index was lower than 1.5.*

If kok-saghyz is sown in the middle of May, the best time for harvesting is mid-October, in southern and central Finland. The results obtained in 1943, 1944, and 1946 indicate that the rubber content of the dry matter of roots will then range from 6 to 9 %, averaging 7.9 %, if plants grow under normal conditions. The rubber content of the fresh weight will be 1.6—2.2 %, averaging 1.8—1.9 %. If, under favourable conditions, dense sowing in rows results in 6000—7000 kg. of roots per ha. (cp. p. 63) in Finland, it means a yield of 125—135 kg. of rubber per ha., provided that roots are harvested at the proper time in the autumn of the first growing season.

In order to illustrate the changes occurring in dry matter, rubber, and resin contents after the first growing season root samples were taken at different dates during the second growing season. Usual dates for samples from the second year stands were early in spring after melting of snow, and at midsummer, or at dates recommended by several investigators as the best dates of harvesting for second year stands (cp. p. 81). At Tikkurila and some other localities samples were taken 3—8 times during the second season. Dry matter content, rubber and resin contents of dry matter, and rubber content of fresh roots for these samples are given in Tables 35—38.

By way of comparison, the corresponding figures for the same stands in the autumn of the first growing season are included in Tables 35—38. Figures 33—36 show the changes in the dry matter, rubber, and resin contents during the second summer. Results are based on investigations of four years.

Tables 35—38 and Figure 33 indicate a sharp decrease in the dry matter content of kok-saghyz roots during winter. When growth period ended in autumn dry matter content was about 25 % of the fresh weight of roots, but early in the next spring it was only 10—15 % of the fresh weight.

Great reduction in dry matter during winter is naturally due to respiration losses, which are heaviest late in autumn when the plant is prevented from drawing nutrients from the soil but has not yet entered dormancy, and also early in spring when the plant starts growth after disappearance of snow cover.

A considerable part of the dry matter of roots consists of carbohydrates, inulin being the most important of them. In the laboratory of State Alcohol Monopoly in Helsinki the dry matter of first year roots was found to contain 30—40 % inulin in autumn. Inulin is the most important reserve substance of kok-saghyz plants, and chiefly the amount of inulin is affected by dry matter losses during winter (cp. 40; 133, p. 156).

After winter the dry matter content of roots increased again in early summer. In 1943, 1944, and 1945 samples were also taken in September, and it was observed that the dry matter content of roots was highest at the end of July and at the begin-

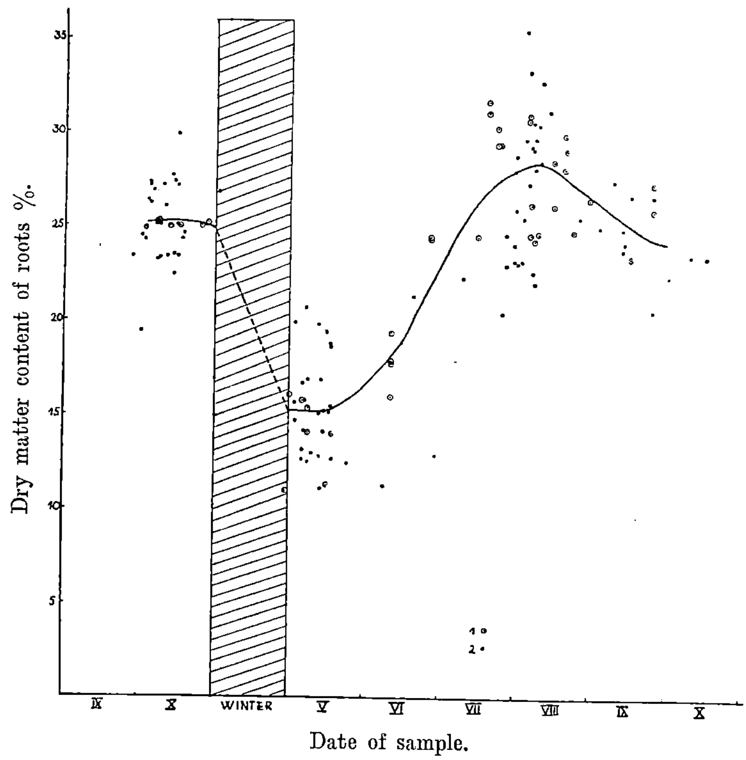


Figure 33. Dry matter content of roots in the autumn of sowing year and at different dates during the second growing season in the years 1943—1947. 1 = values obtained at Tikkurila, 2 = other values.

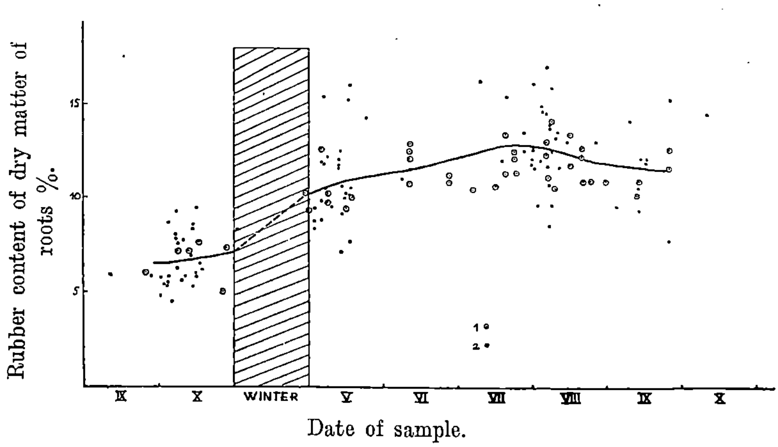


Figure 34. Rubber content of the dry matter of roots in the autumn of sowing year and at different dates during the second growing season in the years 1943—1947. 1 = values obtained at Tikkurila, 2 = other values.

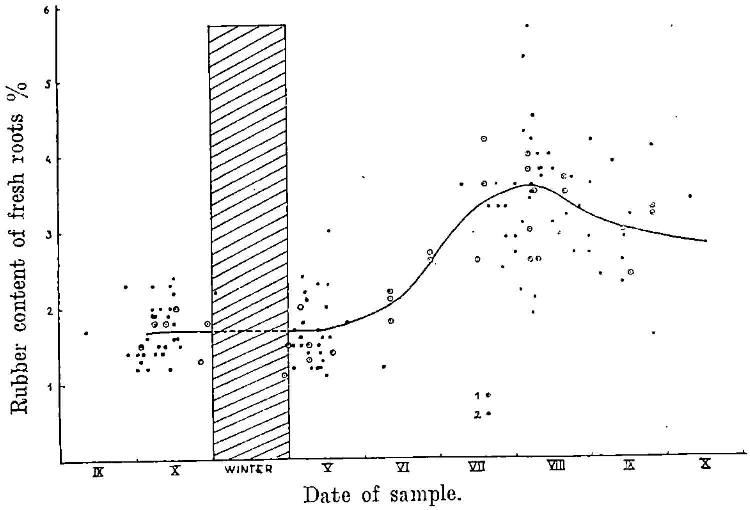


Figure 35. Rubber content of fresh roots in the autumn of sowing year and at different dates during the second growing season in the years 1943—1947.
1 = values obtained at Tikkurila, 2 = other values.

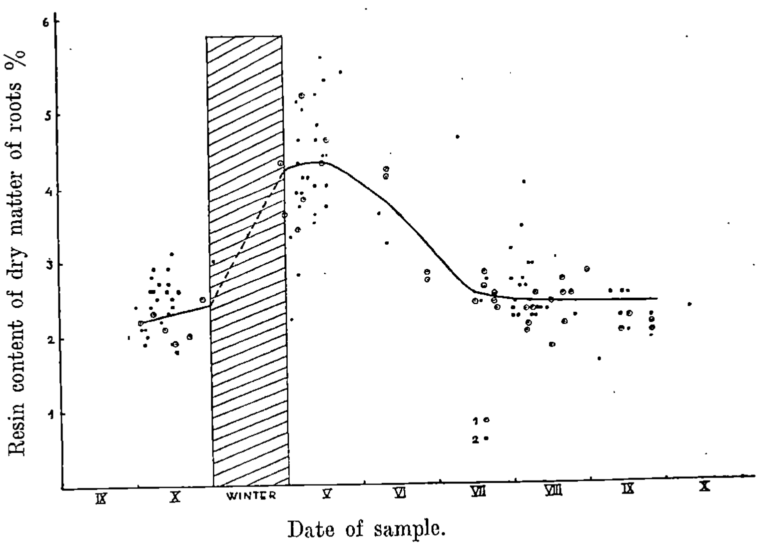


Figure 36. Resin content of the dry matter of roots in the autumn of sowing year and at different dates during the second growing season in the years 1943—1947.
1 = values obtained at Tikkurila, 2 = other values.

Table 35. Dry matter, rubber and resin contents of kok-saghyz roots at different dates in the years 1943—1944.

Locality and date of sowing in 1943	Date of sample	Dry matter %	Rubber in dry matter %	Rubber in fresh weight %	Resin in dry matter %
Tikkurila	Oct. 2 1943	24.9	6.0	1.5	2.2
May 25	May 18 1944	14.0	10.0	1.4	4.6
(clay soil)	Aug. 9 »	24.7	10.5	2.6	2.5
	Sept. 16 »	23.4	10.1	2.4	2.2
Tikkurila	July 15 1944	24.5	10.6	2.6	2.4
June 17	Aug. 8 »	24.3	14.1	3.5	2.3
(sand soil)	Sept. 13 »	24.9	11.9	3.0	2.0
Fiskars	Sept. 28 1943	23.4	5.8	1.4	2.0
May 8	May 8 1944	12.5	10.9	1.4	5.0
	July 9 »	22.3	16.2	3.6	4.6
	Sept. 4 »	25.0	9.5	2.4	1.6
	Oct. 10 »	23.5	14.5	3.4	2.3
Jomala	Nov. 6 1943	26.8	8.3	2.2	3.0
May 7	May 18 1944	12.7	10.5	1.4	4.4
	July 25 »	20.4	12.0	2.5	2.4
Kangasala	Sept. 11 1943	29.4	5.9	1.7	3.0
May 10	May 24 1944	12.5	14.3	1.8	5.5
	July 27 »	24.6	13.5	3.3	—
Leteensuo	Oct. 15 1943	23.4	9.4	2.2	3.1
May 15	May 15 1944	19.4	10.2	2.0	5.7
	July 27 »	23.0	12.5	2.9	—
Maaninka	Oct. 1 1943	24.5	5.7	1.4	2.4
May 17	July 20 1944	21.3	15.4	3.3	2.7
	Oct. 16 »	23.4	11.9	2.8	2.0
Tammisto	Oct. 8 1943	23.3	6.2	1.4	2.4
June 9	May 13 1944	11.1	12.5	1.4	5.2
	Aug. 7 »	22.6	8.5	1.9	2.5
	Sept. 25 »	20.6	7.7	1.6	1.9

ning of August. Up to 35.5 % dry matter contents were found. After that the dry matter content in roots declined and was at the end of September about the same as in the autumn of the first year.

Root samples taken at Tikkurila in 1946 showed that dry matter in roots increased very rapidly up to about 30 % (p. 101, Fig. 39). Decrease occurred after this but it was not so sharp as the increase had been. It is probable that on most plantings samples were not taken at the time of highest dry matter content, and therefore dry matter contents of over 30 % are unusual.

Table 36. Dry matter, rubber and resin contents of kok-saghyz roots at different dates in the years 1944—1945.

Locality and date of sowing in 1944	Date of sample	Dry matter %	Rubber		Resin in dry matter %
			in dry matter %	in fresh weight %	
Tikkurila a .... (sand soil) May 14	June 11 1945	19.4	10.7	1.8	4.1
	July 23 »	29.4	12.1	3.6	2.5
	Aug. 21 »	29.1	10.9	3.2	2.1
Tikkurila b .... (sand soil) May 14	Oct. 16 1944	25.0	7.6	2.0	1.9
	April 20 1945	11.0	10.2	1.1	4.3
	July 24 »	29.4	11.3	3.3	2.3
	Aug. 15 »	28.5	13.4	3.8	1.8
	» 30 »	26.5	10.9	2.9	2.8
Tikkurila ...... (clay soil) June 5	Oct. 26 1944	25.0	5.0	1.3	2.0
	May 15 1945	11.3	9.4	1.1	4.3
	June 11 »	16.0	10.7	1.8	4.1
	July 23 »	30.3	12.5	3.7	2.4
	Aug. 15 »	26.1	11.8	3.1	2.4
	» 24 »	24.8	10.7	2.7	2.5
Fiskars .... May 31	Oct. 11 1944	23.4	5.8	1.4	2.2
	June 8 1945	11.3	11.0	1.2	3.6
	July 7 »	30.6	11.7	3.5	2.4
Hanko .... May 19	Oct. 14 1944	23.5	8.5	2.0	2.3
	June 11 1945	19.4	11.5	2.2	3.2
	Aug. 6 »	29.3	11.7	3.4	2.1
Nokia I .... May 27	Oct. 17 1944	24.3	6.5	1.6	1.8
	May 5 1945	12.7	11.9	1.5	4.3
	Aug. 8 »	29.7	12.5	3.7	2.2
Nokia II ...... May 27	Oct. 18 1944	24.7	6.2	1.5	2.6
	May 5 1945	13.2	8.8	1.2	5.1
	July 30 »	23.2	11.8	2.7	2.7

When changes occurring in rubber content between the autumn of the first and the autumn of the second year (Fig. 34) were observed it was noted that *the relative proportion of rubber in the dry matter increased continuously until it was highest at the end of July or beginning of August*, or at the same time as the dry matter content was highest. Up to 17 % of the dry matter was rubber. During September and October rubber content generally decreased to 9—12 %.

The relative proportion of rubber in dry matter was often almost doubled during winter, but its relative proportion in the fresh weight

Table 37. Dry matter, rubber and resin contents of kok-saghyz roots at different dates in the years 1945—1946.

Locality and date of sowing in 1945	Date of sample	Dry matter %	Rubber in dry matter %	Rubber in fresh weight %	Resin in dry matter %
Tikkurila	Oct. 28 1945	25.2	7.3	1.8	2.5
May 26	May 8 1946	15.4	9.7	1.5	3.8
	June 11 »	17.9	12.5	2.2	4.1
	June 27 »	24.5	10.8	2.6	2.7
	July 19 »	31.1	13.4	4.2	2.6
	Aug. 5 »	30.7	12.3	3.8	2.0
	» 20 »	28.1	12.2	3.5	2.5
	Sept. 25 »	25.9	12.6	3.3	2.1
Tikkurila	—	—	—	—	—
June 2	May 8 1946	14.1	11.2	1.6	5.2
	June 11 »	17.8	12.1	2.2	4.2
	» 27 »	24.4	11.2	2.7	2.8
	July 19 »	31.7	11.3	3.6	2.8
	Aug. 5 »	31.0	13.0	4.0	2.3
	» 20 »	29.9	12.7	3.7	2.7
	Sept. 25 »	27.3	11.6	3.2	2.0
Fiskars	Oct. 5 1945	26.9	4.5	1.2	2.0
May 10	May 2 1946	14.7	8.3	1.2	2.8
	July 31 »	28.8	12.6	3.6	2.2
	Sept. 25 »	26.7	15.3	4.1	2.2
Hanko	Oct. 2 1945	24.3	5.4	1.3	—
May 22	May 14 1946	15.2	10.6	1.6	4.7
	Aug. 3 »	25.5	12.0	3.1	2.6
	Sept. 16 »	26.7	12.1	3.2	2.5
Kangasala	Oct. 9 1945	27.2	5.6	1.5	2.5
May 30	May 17 1946	15.5	10.1	1.6	5.4
	Aug. 10 »	28.5	13.5	3.8	2.3
	Sept. 9 »	27.5	14.1	3.9	2.5
Maaninka	Oct. 4 1945	27.2	5.8	1.6	1.9
May 19	May 2 1946	19.9	8.7	1.7	2.2
	July 31 »	26.0	16.1	4.2	2.3
	Aug. 26 »	25.5	13.0	3.3	2.2
Mikkeli	Oct. 4 1945	27.3	5.5	1.5	2.1
May 30	May 17 1946	18.7	7.6	1.4	3.7
	Aug. 1 »	23.1	11.6	2.7	2.4
	Sept. 14 »	24.2	12.1	2.9	2.5
Ruukki	Oct. 3 1945	26.4	5.3	1.4	2.1
May 28	May 13 1946	16.9	7.1	1.2	4.6
	July 30 »	24.1	12.1	2.9	3.1
	Sept. 13 »	24.9	9.3	2.3	2.2
Savio	Oct. 1 1945	24.5	4.8	1.2	—
May 30	May 9 1946	13.0	9.5	1.2	4.1
	July 31 »	28.0	12.7	3.6	2.3
	Sept. 13 »	23.8	10.5	2.6	2.2

Table 38. Dry matter, rubber, and resin contents of kok-saghyz roots at different dates in the years 1946—1947.

Locality and date of sowing in 1946	Date of sample	Dry matter %	Rubber in dry matter %	Rubber in fresh weight %	Resin in dry matter %
Tikkurila ...... May 11	Oct. 8 1946	25.3	7.1	1.8	2.3
	May 5 1947	15.8	12.6	2.0	3.4
	Aug. 6 »	26.2	11.1	3.0	2.0
Tikkurila ...... May 21	Oct. 12 1946	25.0	7.1	1.8	2.1
	April 30 1947	16.1	9.3	1.5	3.6
	Aug. 6 »	24.6	10.4	2.6	2.1
Fiskars .... May 23	Oct. 4 1946	26.3	8.6	2.3	2.1
	May 17 1947	18.8	16.0	3.0	4.0
	Aug. 9 »	30.4	13.2	4.0	2.2
Hanko .... May 21	Oct. 15 1946	29.9	6.0	1.8	2.4
	May 12 1947	15.1	11.6	1.7	3.5
	Aug. 4 »	35.5	14.9	5.3	3.4
Leteensuo ..... May 21	Oct. 14 1946	22.6	5.3	1.2	2.9
	May 14 1947	14.1	9.1	1.3	4.8
	Aug. 8 »	22.0	9.6	2.1	2.2
Maaninka ...... May 21	Oct. 8 1946	25.1	7.5	1.9	2.9
	May 12 1947	19.8	11.7	2.3	3.6
	Aug. 7 »	26.2	13.7	3.6	2.4
Mikkeli .... May 22	Oct. 7 1946	25.3	9.2	2.3	2.8
	May 7 1947	20.7	10.4	2.2	3.9
	Aug. 4 »	29.7	14.6	4.3	2.7
Mouhijärvi .... May 25	Oct. 15 1946	25.0	9.4	2.4	2.5
	May 2 1947	15.7	9.4	1.5	3.3
	Aug. 5 »	27.3	14.5	4.0	2.6
Nokia .... May 21	Oct. 10 1946	26.1	7.7	2.0	2.7
	May 16 1947	15.2	15.2	2.3	4.4
	Aug. 5 »	33.3	17.0	5.7	4.0
Pälkäne .... May 22	Oct. 14 1946	27.4	8.3	2.3	2.7
	May 6 1947	15.8	15.4	2.4	4.6
	Aug. 8 »	28.1	15.8	4.5	2.9
Ruukki .... May 27	Oct. 7 1946	25.1	7.8	2.0	2.6
	May 5 1947	16.7	9.8	1.6	3.9
	Aug. 7 »	29.2	13.9	4.2	2.9
Savio .... May 21	Oct. 13 1946	27.7	6.9	1.9	2.6
	May 8 1947	16.9	12.2	2.1	4.1
	Aug. 14 »	31.2	13.0	4.0	2.3
Vihti .... May 22	Oct. 7 1946	23.2	8.0	1.9	2.4
	May 12 1947	12.8	12.0	1.5	4.0
	Aug. 2 »	23.2	9.6	2.2	2.2
Ylistaro .... May 25	Oct. 15 1946	27.2	5.8	1.6	1.9
	May 6 1947	14.2	11.8	1.7	3.7
	Aug. 11 »	32.7	11.6	4.8	2.3

remained more or less the same (Figures 34 and 35). Resin content of dry matter increased also (Fig. 36), but its relative proportion in fresh weight remained unchanged. In some cases, e. g. at Tikkurila in the years 1944—45, the rubber content of fresh roots decreased during winter. This may be due to root breaks caused by frost heaving. At sample taking all branches of roots could not be taken from the soil. According to investigations (133, p. 126), tips and branches of roots contain relatively more rubber than the upper parts of the root, and the decrease in rubber content was probably due to the loss of these parts. It is, however, more probable that the decrease in the relative proportion of rubber in the fresh weight of roots was due to the high moisture content of roots at time of sampling.

Observations on changes in the surface layer of roots and in above-ground growth were made at Tikkurila and other localities in 1944—47 at different dates. A comparison of the results of these observations to the dry matter and rubber contents of fresh roots showed the main stages of development of kok-saghyz during the second growing season (Table 39).

There are no distinct limits between the five stages of development reported in Table 39. It is evident that in the middle of summer and for some time after, the rubber content of fresh roots is directly proportional

Table 39. Development of kok-saghyz roots and above-ground growth during the second growing season.

Date	Description of root.	Description of above-ground growth	Dry matter %	Rubber in dry matter %	Rubber in fresh weight %
April—May	1. Early in summer after disappearance of snow cover root cortex is pale and hard.	Rosette small and yellowish (Figures 14 and 15).	10—15	9—12	1—2
May—June	2. Fine threads appear on roots at the beginning of growing season, disappearing after a few weeks. Pale cortex becomes furrowed and roots become supple (Fig. 16).	Rosette green, grows quickly, buds appear, flowering begins and reaches height (Fig. 2).	15—20	10—14	1—2
June—July	3. Cortex dark and furrowed, roots supple, surface tissues dying. Dark cortex becomes easily wet (Fig. 17).	Seed formation begins and reaches height, flowering terminates, leaves begin to wilt.	25—30	10—15	2—4
July—Aug.	4. Dark cortex partly so disintegrated as to render the netlike texture of the rubber in the old cortical tissue visible on the pale new cortex (Fig. 18).	Plants in dormancy, later a small rosette begins to grow (Fig. 19).	25—35	10—17	3—6
Sept.—Oct.	5. Old cortical tissue completely disappeared, roots hard, brittle, with pale cortex, like first year roots in autumn	New rosette formed.	24—26	9—12	2—3

to the amount of rubber from the old cortical tissue left on the surface of the new cortical tissue. MASHTAKOV (75, ref. 133, p. 124) observed considerable increase in the relative proportion of rubber up to the time of the disintegration of the organic substances other than rubber in the old cortical tissue. After this the rubber in the old cortical tissue is gradually sloughed off. According to EMELJANOVA (30, ref. 147, p. 26) the rubber content of the dry matter of roots is then reduced to 9—11 %.

The highest yield is probably secured under conditions unfavourable for the disintegration of the old tissue but favourable for the quick development of the new tissue. As organic matter decomposes slowly in Finnish climate it is evident than in these areas it is easier to recover the rubber of the old cortical tissue than, for instance, in black earth areas in eastern Europe where decomposition of organic matter occurs more quickly. It is true that supply of nutrients, temperature, and length of growing season are there more favourable than in Finland, but the higher precipitation and longer days of northern areas have also been found to favour the development of the plant (cp. p. 23).

Experiments in Finland in 1944—47 indicate, however, that fluctuations of rubber content are much greater for second year fresh roots harvested in different years from different stands at the same dates than for first year roots (cp. Fig. 35). Different weather conditions of different years may be responsible for this (cp. p. 27), for weather conditions greatly influence the development of the plant, especially the formation of the new and disintegration of the old cortical tissue. Both on sand and on clay soil new cortical tissue was formed on the roots, and only threads of the old tissue were left at Tikkurila at the beginning of August 1944. In a similar stand in 1946 the old tissue was still unbroken in samples taken in the middle of October. An examination of weather conditions at Tikkurila during those years shows (cp. p. 24) that very little rainfall occurred in July in 1946, whereas precipitation in the July of 1944 was higher than normal. Low precipitation in July evidently retarded the development of the new cortical tissue in 1946, as the highest rubber content of dry matter at Tikkurila was only 13.4 %.

The final yield of rubber is naturally determined by the yield of fresh roots as well as by rubber content. As it was impossible to calculate the yield of fresh roots for all experimental areas, due to war time conditions, the results as to the yields of fresh roots are based on scarcer material than the determination of dry matter, resin, and rubber contents of roots.

Yields of fresh roots, rubber and above-ground parts were determined at different dates during the second growing season in 15 experimental fields. The yields were compared to the corresponding yields obtained from first year stands in autumn. The results are given in Tables 40—42.

Table 40. Yield of roots and rubber from second year stands at different dates in 1945 at Tikkurila, as compared to the yield from first year stands in autumn 1944.

Locality and date of sowing 1944	Date of sample	Yield of roots		Number of plants per row meter	Average root weight g.	Rubber			
		kg. per ha.	rel. number			in dry matter %	in fresh weight %	kg. per ha.	rel. number
Tikkurila a. ..	Oct. 25 1944	**1 680**	**100**	12.3	4.8	5.0	1.3	**21**	**100**
June 5	May 15 1945	1 570	93	15.5	3.5	9.4	1.1	17	81
(clay soil)	June 11 »	950	57	12.3	2.7	10.7	1.8	17	81
	July 23 »	1 550	92	12.3	4.4	12.5	3.7	57	271
	Aug. 15 »	1 820	108	8.2	6.6	11.8	3.1	56	267
	Aug. 24 »	2 630	157	10.5	7.5	10.7	2.7	69	329
Tikkurila b. ..	Oct. 16 1944	**4 310**	**100**	27.4	4.6	7.6	2.0	**86**	**100**
May 14	Apr. 20 1945	4 290	100	24.0	5.2	10.2	1.1	47	55
(sand soil)	July 24 »	3 430	80	12.0	8.6	11.3	3.3	113	131
	Aug. 15 »	3 960	92	12.3	9.7	13.4	3.8	150	174
	» 30 »	4 410	102	12.0	11.0	10.9	2.9	128	149

Table 41. Yield of roots, rubber, and leaves from second year stands at different dates in 1946 as compared to the yield from first year stands in autumn 1945 or in spring 1946.

Locality and date of sowing 1945	Date of sample	Yield of roots		Number of plants per row meter	Average root weight g.	Rubber				Yield of rosettes	
		kg. per ha.	rel. number			in dry matter %	in fresh weight %	kg. per ha.	rel. number	kg. per ha.	rel. number
Tikkurila a.	Oct. 28 1945	5 480	125	40.5	5.4	7.3	1.8	99	150	7 750	20
May 26	April 24 1946	5 500	125	52.0	4.2	10.6	1.5	83	126	3 740	10
	May 8 »	**4 380**	**100**	33.6	5.2	9.7	1.5	**66**	**100**	3 380	9
	June 11 »	5 050	115	40.0	5.1	12.5	2.2	111	168	**38 000**	**100**
	» 27 »	4 160	95	45.0	3.7	10.8	2.6	112	170	18 000	47
	July 19 »	3 950	90	36.0	4.4	13.4	4.2	166	252	6 250	16
	Aug. 5 »	4 580	105	35.5	5.2	12.3	3.8	174	264	4 050	11
	» 20 »	4 380	100	32.3	5.4	12.2	3.5	153	232	2 280	6
	Sept. 25 »	5 730	131	24.5	9.3	12.6	3.3	189	286	3 120	8
Tikkurila b.	May 8 1946	**4 810**	**100**	58.5	3.3	11.2	1.6	**77**	**100**	3 750	12
June 2	June 11 »	5 750	120	64.0	3.6	12.1	2.2	127	165	**36 250**	**100**
	» 27 »	4 450	93	58.0	3.1	11.2	2.7	120	156	18 000	50
	July 19 »	2 530	53	42.5	2.4	11.3	3.6	91	118	5 000	7
	Aug. 5 »	4 330	90	52.8	3.3	13.0	4.0	173	225	4 150	11
	» 20 »	4 130	86	37.8	4.4	12.7	3.7	153	199	1 520	4
	Sept. 25 »	5 400	112	43.5	5.0	11.6	3.2	173	225	2 150	6
Fiskars	Oct. 5 1945	**3 290**	**100**	16.6	6.9	4.5	1.3	**43**	**100**	**12 000**	**100**
May 10	May 2 1946	3 030	92	15.0	7.1	8.3	1.2	36	84	2 290	19
	July 31 »	3 540	108	11.8	10.5	12.6	3.6	127	295	7 710	64
	Sept. 25 »	3 540	108	10.2	12.2	15.3	4.1	145	337	4 290	36
Hanko	Oct. 2 1945	**3 570**	**100**	11.4	11.0	5.4	1.3	**46**	**100**	**13 140**	**100**
May 22	May 14 1946	1 910	54	9.4	7.1	10.6	1.6	31	67	2 200	17
	Aug. 3 »	2 170	61	4.4	17.3	12.0	3.1	67	146	—	—
	Sept. 16 »	1 990	56	4.0	17.5	12.1	3.2	64	139	—	—
Ruukki	Oct. 3 1945	**1 540**	**100**	13.8	4.2	5.3	1.4	**22**	**100**	**4 320**	**100**
May 28	May 13 1946	1 630	106	15.6	4.0	7.1	1.2	20	91	650	15
	July 30 »	2 720	177	11.2	9.1	12.1	2.9	79	359	8 000	185
	Sept. 13 »	4 210	273	10.8	14.8	9.3	2.3	97	441	5 330	123

Table 42. Yield of roots, rubber, and leaves from second year stands at different dates in 1947 as compared to the yield from first year stands in autumn 1946.

Locality and date of sowing 1946	Date of sample	Yield of roots		Number of plants per row meter	Average root weight g.	Rubber				Yield of rosettes	
		kg. per ha.	rel. number			in dry matter %	in fresh weight %	kg. per ha.	rel. number	kg. per ha.	rel. number
Tikkurila a.	Oct. 8 1946	**5 180**	**100**	36.5	5.0	7.1	1.8	**93**	**100**	**2 790**	**100**
May 11	May 5 1947	4 460	86	36.8	5.3	12.6	2.0	89	96	1 540	45
	Aug. 6 »	7 050	136	33.5	7.4	11.1	3.0	204	219	3 360	120
Tikkurila b.	Oct. 8 1946	**7 890**	**100**	94.8	2.9	7.1	1.8	**142**	**100**	**6 070**	**100**
May 21	April 30 1947	8 040	102	78.8	3.6	9.3	1.5	121	85	3 460	57
	Aug. 6 »	7 620	97	89.0	3.0	10.4	2.6	198	139	3 640	60
Vihti	Oct. 7 1946	**1 850**	**100**	10.2	5.4	8.0	1.9	**35**	**100**	**4 160**	**100**
May 22	May 12 1947	940	51	5.8	4.9	12.0	1.5	14	40	380	9
	Aug. 2 »	2 850	154	5.4	15.8	9.6	2.2	63	180	6 850	165
Leteensuo	Oct. 4 1946	**2 100**	**100**	33.8	2.5	5.3	1.2	**25**	**100**	**6 900**	**100**
May 21	May 14 1947	1 500	71	27.0	2.2	9.1	1.3	20	80	1 250	18
	Aug. 8 »	6 460	308	26.0	8.7	9.6	2.1	136	544	7 030	102
Maaninka	Oct. 8 1946	**4 540**	**100**	55.8	2.8	7.5	1.9	**86**	**100**	**4 800**	**100**
May 21	May 12 1947	5 140	113	55.0	3.6	11.7	2.3	118	137	2 370	49
	Aug. 7 »	4 940	109	38.6	4.5	13.7	3.6	178	207	4 860	101
Mikkeli	Oct. 7 1946	**2 650**	**100**	51.6	1.8	9.2	2.3	**61**	**100**	**1 630**	**100**
May 22	May 7 1947	4 290	162	46.4	3.2	10.4	2.2	94	154	1 740	45
	Aug. 4 »	4 860	183	40.0	4.3	14.6	4.3	209	313	5 690	350
Mouhijärvi	Oct. 15 1946	**5 170**	**100**	45.0	3.4	9.4	2.4	**124**	**100**	**6 070**	**100**
May 25	May 2 1947	5 900	114	46.6	3.8	9.4	1.5	89	80	1 930	32
	Aug. 5 »	5 230	101	42.8	3.7	14.5	3.0	209	169	5 270	87
Ruukki	Oct. 7 1946	**2 290**	**100**	17.0	4.7	7.8	2.0	**46**	**100**	**2 860**	**100**
May 27	May 5 1947	3 310	145	25.8	4.5	9.8	1.6	53	115	970	34
	Aug. 7 »	2 860	125	17.6	5.7	13.9	4.2	117	393	4 570	160

With regard to the yields of roots and rubber reported in Tables 40—42 the experimental fields can be divided into 3 groups.

1. The first group consists of plantings with *distinct increase in the yield of roots* during the second growth summer as compared to the yield of roots obtained in the autumn of the first year (Fig. 37). Five plantings out of the examined 15 belong to this group.

The localities of these plantings were: Ruukki in 1946, Leteensuo, Mikkeli, Vihti, and Tikkurila (a) in 1947 (Tables 40 and 42).

Kok-saghyz stands are characterized by an increase in rubber content in the middle of the second growth summer. This increase, together with the distinct increase in the yield of roots resulted at Ruukki in 1946, at Leteensuo and Mikkeli in 1947 in three- to fivefold yields of rubber

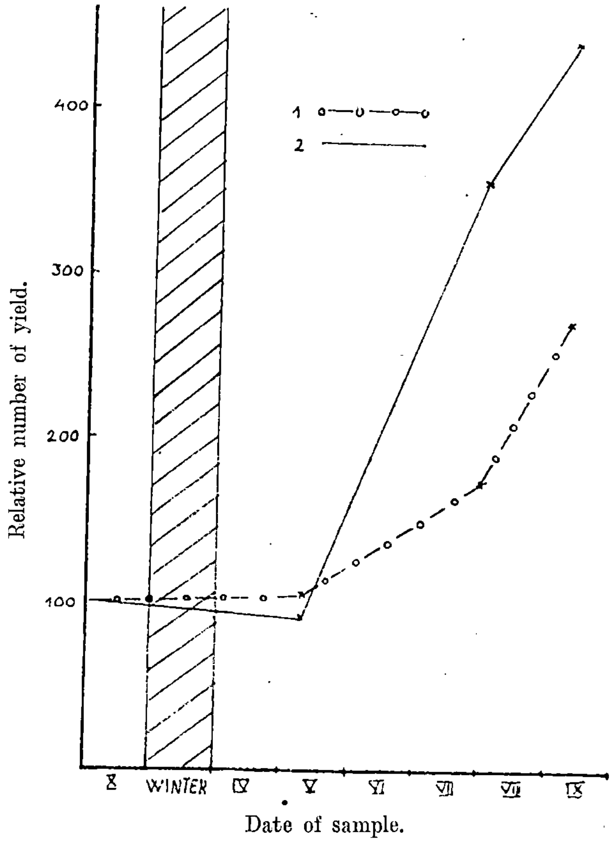


Figure 37. Yield of roots (1) and rubber (2) from second year stand at different dates at Ruukki in 1946, as compared to first year yield in the autumn of 1945 (= 100).

as compared to the yields from first year stands in autumn. At Ruukki (Fig. 37) roots were also harvested in mid-September, and the increase in the yield occurring during August and September due to new growth in roots was great enough to compensate for the reduction of rubber content in August and September, and even to increase the yield of rubber with 23 %. When reasons for this considerable new growth were searched it was observed that in these areas the yield had been very low in the autumn of the first season, mostly only about 20 kg. of rubber per ha. Unfavourable conditions, chiefly drought and probably also too late weeding were responsible for the low yield in the first summer.

2. The second group consists of 4 experimental fields which suffered over 30 % winter losses. At Fiskars in 1946 and at Maaninka in 1947 the *new growth* in second year roots was so *vigorous* as to *compensate for winter*

losses in the yield of roots by the end of July. Only at Hanko in 1946 the yield of roots was about 60 % of the first year yield. At Tikkurila (b) in 1945 the new growth had compensated for winter losses by the end of August (Table 40). But in all 4 cases the yield of rubber was up to 3 times as great as in the autumn of the first year (Fig. 38). Test harvestings

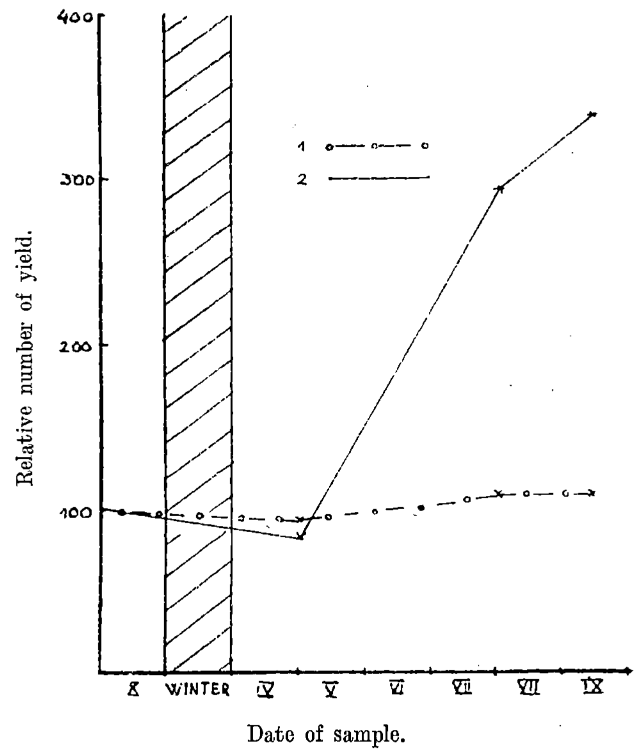


Figure 38. Yield of roots (1) and rubber (2) from second year stand at different dates at Fiskars in 1946, as compared to first year yield in the autumn of 1945 (= 100).

from these stands at Tikkurila in August and September 1945 resulted in 15 % lower yield at the end of August as compared to the yield in mid-August. In this case the old cortical tissue was totally decomposed and sloughed off by the end of August. This reduced the rubber content in fresh roots. At Fiskars the last test harvesting in 1946 was carried out in the middle of September. Loose rubber was found on roots, but the new cortical tissue was fully-developed by this time, and there was an increase in the rubber content of fresh roots resulting in an increase of 6 % in the yield of rubber. But at Hanko in 1946 winter and spring losses resulted in so thin a stand that new growth of roots and increase in rubber content could not compensate for these losses.

3. The third group consists of the remaining 6 plantings. On these plantings winter losses were slight, and *no distinct new growth* was observed *in roots* as compared to the yield in the autumn of the first year, except at Tikkurila (a) in 1945, where an increase of 45 % in the yield of roots occurred between Aug. 15 and Aug. 24 resulting in an increase of 23 % in the yield of rubber (Table 40). As well the rubber content of dry matter as that of fresh weight had declined by that time because of the disintegration and sloughing-off of the old cortical tissue. In 1945 precipitation was very high at Tikkurila in August, 109 mm. (normal 88 mm.). Cultivation operations, weedings and harrowings, which were carried out before rains also hastened the development of the plants and caused vigorous new growth in the roots. The other experimental fields belonging to this group were located at Tikkurila in 1946 (2 plots), and at Mouhijärvi, Ruukki, and Tikkurila in 1947. As these stands were dense, it is evident that under prevailing conditions roots in normally developed dense stands attained their maximum size already during the first growing season, and new growth in the second season was slight.

In 1945 five test harvestings and in 1946 seven test harvestings were carried out at Tikkurila during the second growing season. Results are given in Tables 40 and 42. The following conclusions can be drawn from the data in Fig. 39 and Table 39 with regard to changes in the yields of roots and rubber at different dates and to stages of development of the second year roots:

1. During the first and second stage of development in May and June winter losses in dry matter of roots were compensated for, rosette developed vigorously, flowering began and reached its height. At the same time there was an increase in the rubber content of both the fresh roots and the dry matter, but a *decrease in the yield of fresh roots.*

2. A sharp increase in the dry matter content of roots occurred between the second and the third stage while the decrease in the yield of fresh roots continued.

3. Between the third and the fourth stage the yield of roots almost reached the level it had at the beginning of flowering. Rubber content was highest at this time, and the *yield of rubber higher than at any previous date*. Figure 39 indicates that plants reached this stage when the aboveground growth had been completely withered for 2 weeks. Harvesting at this stage produced hard and brittle roots with the old cortical tissue still left on the roots.

4. Between the fourth and the fifth stage the old cortical tissue was sloughed off resulting in a decrease in rubber and dry matter contents. If vigorous new growth of roots was not possible at this time because

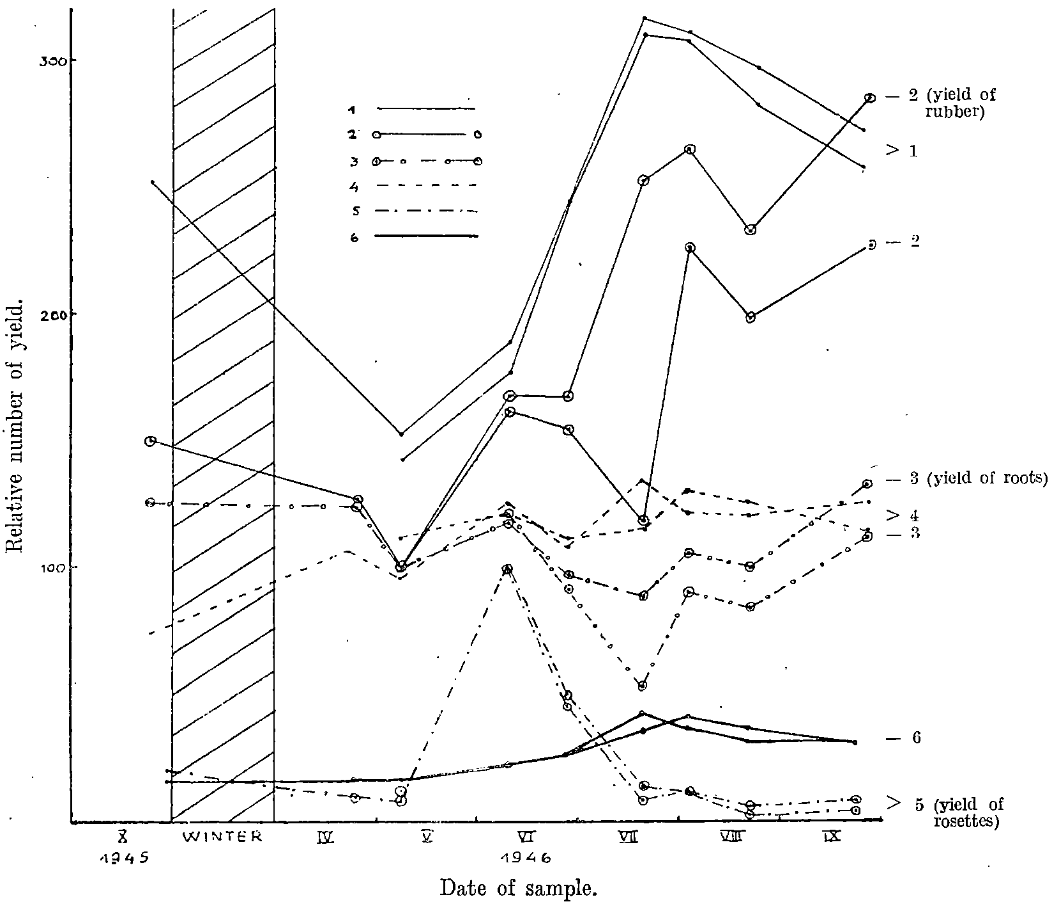


Figure 39. Yield of roots (3) and rubber (2) at different dates at Tikkurila in 1946 (2 plots) as compared to first year yields. Yields in May 1946 = 100. By way of comparison, the same co-ordination includes dry matter content of roots (1), rubber content of dry matter (4), rubber content of fresh roots (6), and yield of rosettes (5). Maximum yield of rosettes = 100.

of drought, or for other reasons, the *yield of rubber declined,* as Figure 39 indicates. In 1946 precipitation was very low at Tikkurila in July and August. The total precipitation during both months was only 62 mm. (normal 158 mm.). During the fifth stage in autumn, vigorous new growth occurred in the roots resulting in *an increase in the yield of rubber.*

A comparison of these results to the results obtained by Knutson (54, ref. 133, p. 121) in U. S. A. shows that he, too, observed the decrease in the fresh weight of the second year roots at the time of maximum flowering. According to Mashtakov's (75, ref. 133, p. 124) investigations, rubber of the old cortical tissue remains in the roots until the peak of seed formation, after which it is sloughed off. As, according to MASHTAKOV (76), no accumulation of rubber occurs in the roots during summer dormancy, it is evident that roots should be harvested immediately after the plants have ceased growing. In Finland this occurred between the third and the fourth stage of development at the end of July or beginning of August, and investigations showed that the rubber and dry matter contents of the roots were highest at that time.

According to the investigations conducted in Finland in the years 1944—47 with regard to the yields of roots and rubber from different plantings during the second growing season, different increases were observed at different localities, chiefly owing to growth conditions during the first and the second growing season. Relatively the highest increase was observed for stands which developed poorly during the first growing season and produced low rubber yields in the autumn of the sowing summer. Relatively the slightest increase was observed for dense stands which wintered well. With these plants new growth in roots was very slight during the second growth summer.

In all tested areas the yield of rubber, however, usually increased during the second growing season over that of the first season. Table 24 (p. 60) shows that only in 1943—44 some plantings produced lower yields after wintering than in the first year. The results obtained in the investigations of the following 3 years, however, indicate that the decrease in the yield may be attributed to the exceptionally mild winter which was unfavourable to the wintering of kok-saghyz. This drawback was heightened by thin stands due to too deep sowing and thinning of plants.

On the basis of the reported facts it can be stated that *under normal conditions the yield of rubber obtained from well-developed dense (30—90 plants per row meter) second year stands after flowering was at least double the yield obtained from first year stands in autumn.*

In the years 1946 and 1947 attempts were made to find out the vigour of growth of second year stands at time of harvesting by determining the relation between the weight of rosettes and the weight of roots = *the weight relation index*, as was done for first year stands (cp. p. 82). In the dates of harvesting experiments for second year stands conducted at Tikkurila in 1946 (Table 41; Fig. 39) the rubber content of roots was highest at the time when growth ceased. Similar indices were calculated on the results of the dates of harvesting experiments for first year stands (cp. p. 83). Accumulation of rubber in roots was over when weight relation index was about 1. In second year stands above-ground growth is usually more abundant than in first year stands, and evidently weight relation index at the time when growth and accumulation of rubber have ceased is somewhat higher than in the first summer. To prevent the rubber of the old cortex from sloughing off harvesting should not be done too late when weight relation index is under 1, or too early. This is clearly shown by the rubber contents of the dry matter of roots at the time of harvesting in 1946—47.

If the plantings of the years 1946 and 1947 are divided into two groups according to whether the weight relation index is between 1 and 1.6, or lower or higher, and if attention is paid to the dates of samples and to the rubber content of dry matter, it is possible to make the grouping given in Table 43. In addition to the results obtained at Tikkurila also results obtained at other localities have been used. The results are from 26 different localities and 37 test harvestings during the years 1946—47.

Table 43. Weight relation index and rubber content of the dry matter of roots in second year stands at time of harvesting in the years 1946—1947.

I Weight relation index 1.6—1.0					II Weight relation index lower than 1.0 or higher than 1.6				
Locality and year	Date of sample	Rubber in dry matter of roots %	Yield of rosettes kg. per ha.	Weight relation index	Locality and year	Date of sample	Rubber in dry matter of roots %	Yield of rosettes kg. per ha.	Weight relation index
1946					**1946**				
Fiskars	Sept. 25	15.3	4 290	1.2	Fiskars	July 31	12.6	7 710	0.2
Kangasala ..	Aug. 10	13.5	3 800	1.0	Kangasala ..	Sept. 9	14.1	1 750	0.5
Ruukki	Sept. 13	9.3	5 330	1.3	Mikkeli	Aug. 1	11.6	3 230	2.1
Savio	July 31	12.7	3 230	1.0	»	Sept. 14	12.1	1 700	0.5
Tikkurila ...	Aug. 5	13.0	4 150	1.0	Ruukki	July 30	12.1	8 000	2.9
					Tikkurila a.	Aug. 5	12.3	4 050	0.9
					»	» 20	12.2	2 280	0.5
1947					»	Sept. 25	12.6	3 130	0.5
					Tikkurila b..	July 19	11.3	5 000	2.0
Hanko	Aug. 4	14.9	3 600	1.2	»	Aug. 20	12.7	1 530	0.4
Leteensuo ..	» 8	9.6	7 030	1.1	»	Sept. 25	11.6	2 150	0.4
Maaninka ..	» 7	13.7	4 860	1.0	Savio	» 13	10.5	200	0.1
Mikkeli	» 4	14.6	5 690	1.2	Ylistaro	July 30	9.3	18 000	4.7
Mouhijärvi ..	» 5	14.5	5 270	1.0	»	Sept. 16	9.7	750	0.1
Nokia	» 5	17.0	5 330	1.4					
Peipohja ...	» 9	11.5	7 830	1.5	**1947**				
Pälkäne	» 8	15.8	3 330	1.1	Fiskars	Aug. 9	13.2	8 000	2.1
Ruukki	» 7	13.9	4 570	1.6	Jomala	» 15	11.5	3 150	0.9
Savio	» 14	13.0	4 330	1.0	Kangasala ..	» 6	10.9	4 110	1.7
					Lahti	» 7	12.3	2 690	0.5
					Tikkurila a. .	» 6	10.4	3 640	0.5
					» b. .	» 6	11.1	3 360	0.5
					Vihti	» 2	9.6	6 850	2.4
					Ylistaro	» 11	11.6	4 850	0.9
Average		13.5[1]		—			11.6[1]	—	—

[1]) Variance ratio (F) = 11.8**.

Table 43 indicates that in the group with weight relation index 1.0—1.6 rubber content in the dry matter of roots averaged 13.5 % and was 13.0 % or over in 12 cases out of 16. In the other group rubber content averaged 11.6 % and was over 13 % only in 2 cases out of 22. The difference between the means of rubber contents was tested by analysis of variance. Since the variance ratio F was 11.8**, the difference between the means is very significant.

A closer investigation of individual cases showing considerable deviation from the rubber content of the other cases in the same group partly disclosed the reasons for such deviations.

In the first group, rubber content was in three cases, viz. at Ruukki in 1946, at Leteensuo and at Peipohja in 1947, considerably lower than the average of the group. When attention was paid to the conditions in these areas it was observed that during the first summer development of the stands had been poor, and vigorous new growth of roots occurred during the second year. With regard to the poor development and low yield of rubber of first year roots it is evident that the amount of old cortical tissue usually accounting for the high rubber content in the middle of the second growing season was very small in the yields from these stands as compared to the amount of young tissue with low rubber content.

The most conspicuous exceptions for the second group were the results obtained at Kangasala in 1946, and at Fiskars in 1947. The high rubber content of the roots harvested at Kangasala in September is evidently due to the amount of rubber in the old cortical tissue on the roots. It is possible that the soil of the test area, heavy loam, retarded the disintegration of the old cortical tissue.

At Fiskars the rubber content of the dry matter of roots was 13.2 % already on August 9, though weight relation index was as high as 2.1. This exception can be attributed to the good farming condition of the fields, and evidently the rubber content of the roots in this area would have exceeded 13.2 % with delayed harvesting. This assumption is confirmed by the result obtained at Fiskars in 1946, when rubber content was 15.3 % on September 25. Likewise at Kangasala in September 1946 the rubber from the old cortical tissue was left on the roots (the field was located on clay soil).

The reported results indicate that the *rubber content of the dry matter of roots was for second year stands highest* after flowering, at the time when *weight relation index was* 1.0—1.5.

The results agree with the results obtained by Germans, though they think that it is best to harvest the roots about a week after seed maturation (cp. p. 81). But exact determination of the beginning and especially of the termination of seed formation and flowering periods is largely a matter of opinion, for flowering and seed formation often continue up to the end of July and beginning of August. Therefore it is difficult to determine the proper time for harvesting only with regard to flowering and seed formation. Nor is it possible to determine exactly the proper time for harvesting by examining roots, except after long experience.

When the best time for harvesting roots in the middle of summer is determined weight relation index may be of importance. Roots are lifted from 1 row meter, for instance, and the relation between the weight of above-ground parts and the weight of roots is calculated. If the index is considerably higher than 1, e. g. 2—3, it is too early to harvest the roots. The best time to begin harvesting in normally developed stands is as soon as weight relation index is reduced to 1—1.5. If weight relation index is below 1, roots should not be harvested until autumn for the dry matter and rubber content of roots declines between the fourth and fifth stage of development (Figure 39). If the plants are allowed to grow until the end of September, vigorous new growth often occurs in the roots, for in normal years the autumns in Finland are favourable for the growth of roots. The amount of rubber produced by this new growth compensates for the rubber which was sloughed off from the roots in the middle of summer. The new growth of roots may even increase the yield of rubber per ha., especially if growth conditions have been unfavourable earlier in summer or during the previous growing season.

Some test harvestings were done at Tikkurila in the years 1945—46 also for third year stands. Results obtained from some experimental plots on sand soil are given in Table 44.

Table 44. Yields obtained from third year stands at Tikkurila in 1945—1946 as compared to yields obtained from second year stands in 1944—1945.

Age of stand	Date of harvestings	Yield of roots kg. per ha.	Number of plants per row meter	Average root weight g.	Dry matter %	Rubber		
						in dry matter %	in fresh weight %	kg. per ha.
2 years	Aug. 8 1944	2 440	20.0	4.9	24.8	13.5	3.3	81
3 »	Apr. 27 1945	1 000	7.5	5.3	13.9	15.7	2.2	22
»	June 11 »	1 000	7.3	5.5	17.2	14.7	2.5	25
»	July 25 »	1 860	7.3	10.2	30.7	14.3	4.4	82
»	Aug. 28 »	1 860	5.4	13.7	24.4	13.7	3.3	61
2 years	June 11 1945	1 430	7.5	5.7	16.7	10.7	1.8	26
»	July 23 »	2 760	7.4	11.5	29.4	12.1	3.6	99
»	Aug. 21 »	2 800	7.0	12.0	29.1	10.9	3.2	90
3 »	Sept. 5 1946	2 620	7.5	10.4	29.9	15.8	4.7	123

Results in Table 44 indicate that the development of kok-saghyz during the third growing season is similar to that in the second season, and no significant increase in the yield of rubber was observed in these areas, suggesting that third year harvesting should be advisable. No mentions have been found in the literature on kok-saghyz recommending harvesting in the third year.

Following conclusions as to the best time for harvesting stands established by spring sowing in the field may be drawn from the reported results:

Owing to short period of growth the rubber content of kok-saghyz roots does not generally reach up to 2 % of the fresh weight of roots during the first growing season though harvesting were done as late in autumn as possible.

With regard to the yield of rubber, root harvesting in the spring of the second season does not secure better yields than harvesting in the autumn of the first season. In some cases the yield of rubber was reduced if harvesting was delayed until the spring of the second season. But harvesting operations were considerably easier than in autumn, as winter heaving loosened the roots.

In Finland the highest yields of rubber were secured from dense (30—90 plants per row meter) second year stands in the years 1946 and 1947. In many cases the yield of rubber obtained in the second summer at the end of July or beginning of August was nearly twice the yield obtained in the previous autumn. With vigorous new growth in the roots there was up to fivefold increase in the yield over the yield in the first year. Though these biennial stands were tested only during 2 years, it seems that biennial stands are most suitable for Finland. Further investigations, however, should be necessary to prove this.

Owing to scarce material it is impossible to state whether it is better to harvest second year roots in the middle of summer, or later in autumn. However, it seems advisable to recover the rubber in the old cortical tissue. If roots are harvested in the middle of summer their drying in open air is also easier than in autumn. The results obtained at Tikkurila also indicate that under normal conditions, and in well-cultivated dense stands the roots have attained the largest possible size by the middle of the second summer. Therefore it is likely that the new growth of roots in autumn will not be able to compensate for the amount of rubber lost with the old cortical tissue, if plants are well developed. Harvesting in the second summer resulted in an exceptionally high increase in the yield for stands with slow development in the first season.

Investigations conducted in Finland seem to prove that for normally developed second year stands in southern and central Finland the rubber content of roots, based on dry matter, is at least 13.5 % at the time of maximum rubber content. Rubber content of fresh weight is 3.5—4.0 %. If the estimated yield of roots from well-developed dense second year stands is 6 000—7 000 kg. per ha., a yield of 210—280 kg. of rubber per ha. is secured with harvesting the roots at the proper time in the middle of summer.

Effect of removal of flowers.

Some investigators in U. S. S. R. have reported higher yields of rubber with removal of flowers (4, p. 80; 128; 101), but different opinions have also been expressed (122). NICHIPOROVICH and IVANITZKAYA (101, p. 38) observed that wounding generally stimulated the developement of latex tubes in the roots.

In U. S. A., SCARTH, GOODING, and SHAW (123) investigated the dormancy of kok-saghyz and observed that removal of flower scapes delayed the dormant period. In this way the growth period of second year plants was prolonged and roots became larger than in the first year plants. If sowing was done between June 12 and 22 the growth period of first year plants was so short that no dormancy occurred. In this case removal of flower scapes had no effect on the size of roots. These investigations indicate that under certain conditions removal of flower scapes is of importance.

The effect of removal of flowers on the yield of rubber was tested at Tikkurila in the summer of 1946. Test area was sown on June 11 1946. Removal of flower stalks was begun as soon as the first flowers appeared on the plants on August 1. The operation was conducted by hand, and stalks were broken off at one-week intervals. Harvesting was carried out November 1 1946. Results are given in Table 45.

Table 45. Effect of removal of flower heads in first year stands at Tikkurila in 1946.

Treatment	Yield of roots kg. per ha.	Numcer of plants per row meter	Average root weight g.	Yield of rosettes kg. per ha.	Dry matter % (in roots)	Rubber (in roots)		
						in dry matter %	in fresh weight %	kg. per ha.
Normal flowering ..	7 600	41.8	6.4	4 940	24.9	7.6	1.9	144
Flower heads removed............	7 660	41.0	6.5	6 290	24.9	7.3	1.8	138

F = 19.2*: minimum significant difference for yield of rosettes 827 kg.; m % 3.3.

Results indicate that in the reported case removal of flowers did not result in any increase in the yield of rubber. But the yield of leaves was influenced by removal of flowers. Plants from which flowers were removed remained green for a longer time than normally flowering plants. Evidently the removal of flowers delayed the dormancy of the plants. As there is no distinct difference in the yield of roots or rubber it seems that the longer period of growth can be attributed to disturbances in the development of the plant due to removal of flowers. No accurate conclusions can be drawn from this one experiment, but the result confirms SCARTH's, GOODIND's, and SHAW's (123) opinion that removal of flowers is of no importance if growth period is short.

Diseases and pests.

Generally, kok-saghyz is not considered susceptible to plant diseases (48, p. 539). But with the expansion of kok-saghyz cultivation damage by some diseases has been found in kok-saghyz stands, though usually to a limited extent.

According to investigations in U. S. A., damping-off was the most serious disease of kok-saghyz in 1942. Species of *Pythium*, *Fusarium*, and *Rhizoctonia* were the fungi most commonly causing damping-off (133, p. 96). The disease, however, could not limit the cultivation of kok-saghyz.

Broken or otherwise damaged tissues of roots have usually proved very susceptible to attacks by fungi, bacteria, and viruses. In U. S. S. R. it is advised to destroy all leaves at harvesting, in order to prevent the spreading of root rot organisms. It is also recommended to locate first and second year plantings far from one another, and it is not considered advisable to grow kok-saghyz twice successively in the same area. To prevent damage by *Sclerotinia* sp. kok-saghyz should not be grown after clover. In U. S. S. R. and in U. S. A. overwinter losses by root rot have been more usual on peat soils than on mineral soils (4, p. 101; 133, pp. 95—98).

Beetles and their grubs must be mentioned among the pests damaging kok-saghyz roots and leaves. The grubs of *Agriotes* sp. dig passages in the roots, and root rot organisms enter the plant through these (3, pp. 43—44). KALINENKO (49), SKARBILOVICH (124), and GHILAROV (38) reported damage by nematodes in kok-saghyz roots. The last mentioned investigator reported stands with 48 % of the roots damaged by *Orobanche ramosa*. Roots may also be injured by black ants *(Lasius niger)*. Plant-lice *(Aphididae)* add to the damage caused by ants. As a result, roots are broken and remain very short and shrivelled, leaves turn yellow, and the plant develops slowly (141; p. 19).

In Finland no widely spread diseases or pests were found to limit the cultivation of kok-saghyz in 1943—47. *Sclerotinia* sp. caused wilting of leaves and rotting of roots at the crown. In the first place this fungus attacked vigorous plants growing apart from others. Damages caused by *Sclerotinia sp.* were observed especially after winter in the years

1944—45 (cp. p. 47). No damage by this fungus was observed in dense stands in 1946—47, except in a few plants at Tikkurila.

Rots occurring at root breaks after winter have been mentioned already (cp. p. 46). In the spring of 1946 sclerotiums of *Typhula* sp. were observed in the wilted parts of the rosettes at Tikkurila. This fungus, however, was not pathogenic; its threads had only penetrated into the dead tissues of the wilted leaves.

Flower scapes were found to die during rainy periods at time of seed formation and later. The disease spred into flower head preventing seed formation. If seeds had already been formed, seed head did not open, and part of the seeds died and dried in the seed heads. An examination of the dead parts of the flower stalks showed that threads of *Fusarium* sp. and *Botrytis* sp. had entered the stalks (Fig. 40). However, it could not be proved that this fungus had been the only cause of destruction. At the determination of the germination of seed collected from these stands, following species of fungi, among others, were found: *Hormodendrum sp. Alternaria sp., Penicillium sp., Botrytis sp., Mucor sp.*, and *Fusarium sp.* The threads of these fungi disturbed germinating seeds and sometimes even destroyed young seedlings.

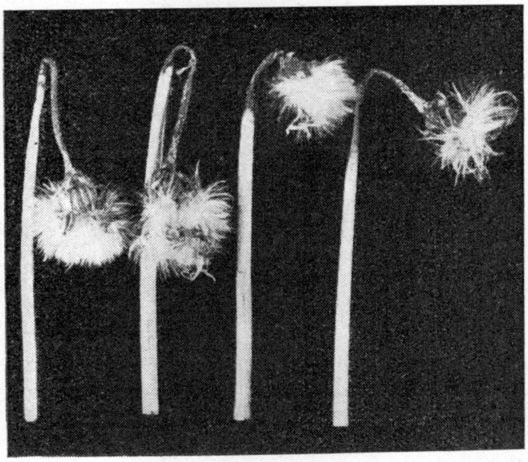


Figure 40. Damage by moulds in kok-saghyz seed heads. Especially noticeable during rains and immediately after. (Orig.)

Destruction of flower and seed heads may also be due to some physiological disturbances caused by excessive moisture and accumulated water in flower heads. The fungi encountered in the samples were probably only secondary factors, though later, at time of germination they appeared as primary causes for destruction. In Sweden a similar disease occurred in greenhouse experiments at bud stage preventing the normal development of flower heads. The disease was attributed to irrigation, for water accumulated easily in the centre of the rosette. When irrigation was applied in a different way the disease vanished (7, p. 187).

Among the pests encountered in Finland may be mentioned the grubs of *Agriotes sp.* Passages dug by these grubs were found in the roots of kok-saghyz at Porvoo in 1943, and at Savio in 1946. The damage caused by the grubs was not estimated, but root samples indicate that it was very slight. In 1946 at Hanko slugs *(Limax agrestis)* destroyed all the rosettes on an area of some ares. Application of unburnt lime limited the damage.

Ants were among the most serious pests injuring roots and leaves at Tikkurila. *Lasius niger* caused the greatest damage. It began to injure kok-saghyz plants at seedling stage breaking thin roots and injuring thicker roots. As a result, roots developed very slowly, and remained short and blunt (Fig. 41). Damages by ants were best observable

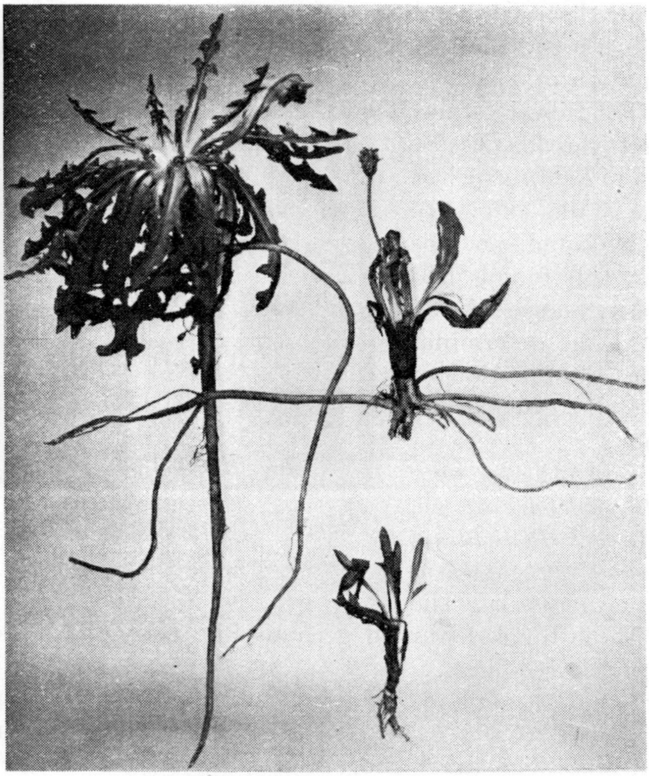


Figure 41. (On the right) Destroyed kok-saghyz plants on sand soil at Tikkurila. Tips of roots blunt. (On the left) Sound kok-saghyz plant of the same age in the same area. (Orig.)

near ditches, at sandy and dry places. Damage by ants was only found on sand soils at Tikkurila. Losses in root yields caused by ants were sometimes estimated at 30 % for well-developed stands. Under unfavourable conditions, during drought periods and on soils with low organic content, losses caused by ants were estimated at 60—70 %. Agrocide insecticides were used to destroy ants. Damage by ants was avoided if kok-saghyz plantings were located on well-fertilized soils with high organic content which did not suffer from drought very much. Plant-lice which are said to appear together with ants were not seen at Tikkurila.

c. *Yield of seed.*

Maximum flowering of kok-saghyz occurs during the second growing season, and the period of flowering is in the second season shorter than in the first season. Generally, it is considered advisable to collect the seed in the second summer. But as there has been shortage of kok-saghyz seed, collection has also been done from first year stands (3, pp. 46, 47; 141, p. 14; 147, p. 24).

ERICSSON (31, p. 8) reports the yield of seed from first year stands in U. S. S. R. as 20—40 kg. per ha., and from second year stands as up to 200 kg. per ha., which must be considered among the highest yields (3, p. 3). In U. S. A., in 1943 5—6 kg. of seed per ha. were collected from some test areas. Seed yields from different areas ranged from 2.5 to 19 kg. per ha. Plantings were early spring sowings, and seed was collected from first year stands. ZEHNGRAFF and AAMODT (139, ref. 133, pp. 110—111) computed a theoretical yield. They counted the number of flowers and the number of seeds per flower on a second year planting and computed the theoretical yield of about 220 kg. per ha. for this area. HURTT's (46, ref. 133 pp. 110—111) calculations resulted in similar figures. In reality it is difficult to secure so high yields as seeds mature unevenly.

As kok-saghyz is pollinated by insects, the number of pollinating insects is significant. This again is depending on weather conditions. So in U. S. A. in 1944 seed production of second year kok-saghyz failed completely because of cold and rainy June (133, p. 111).

In first year stands the height of flowering occurred in August and September, when long rainy periods are common and the relative moisture of air increases. Therefore seed formation was poor in the first summer, and the seed was collected from second year stands. Seed collection was done by hand-picking the open seed heads. Seed heads were then dried at 18—20° C in a thin layer. Cleaning was carried out by means of a clover seed huller and sieves. After this treatment the purity of seed was 95—97 %.

In 1946 a dates of harvesting experiment was carried out for second year stands at Tikkurila. Seed was collected from a given area daily between June 25 and July 23. The collected seed lots were dried, cleaned, and their germination and weight per 1 000 seeds were determined in the spring of 1947. Results of this experiment are given in Table 46. Table 46 also reports the precipitation at time of seed collection, average temperature of day, and the number of insects visiting the flower heads. The number of bees was calculated separately. Besides bees *(Apis mellifica)*, many flies visited the flowers. Bumble-bees *(Bombus* sp.*)* were only seen occasionally.

Table 46. Dates of seed collection experiment from second year stand at Tikkurila in 1946.

Date of harvesting	Proportion of pure seed in total yield %	Weight per 1 000 seeds g.	Germination % in the spring of 1947	Stage of flowering	Number of pollinating insects per are [1])		Precipitation mm.	Average temperature of day °C
					Bees	Others		
June 25	18	0.480	55	s. 6 [2])	50	—	—	20.3
» 26	33	0.480	69	—	23	5	—	20.3
» 27	34	0.520	84	s. 5	23	—	—	18.8
» 28	34	0.530	77	—	20	10	—	18.7
» 29	35	0.510	80	s. 4	15	15	—	16.6
July 1	41	0.510	81	s. 3	5	10	—	14.4
» 2	55	0.500	85	—	3	3	—	15.7
» 3	49	0.500	83	s. 2	8	7	—	18.1
» 4	45	0.490	80	—	8	—	—	18.4
» 6	44	0.470	78	—	5	—	—	19.7
» 7—10	42	0.450	79	s. 1	2	1	—	17.9
» 12—16	40	0.420	75	—	—	—	8.2	19.1
» 17—18	44	0.430	73	—	—	—	—	19.1
» 19—23	37	0.360	54	s. 0+	—	—	2.0	18.6

Table 46 shows that in 1946 weather conditions were extremely favourable for the development of kok-saghyz seed. No rain occurred during the height of flowering and seed formation. As the pollination of kok-saghyz is done by insects weather conditions during the period of flowering are of great importance. Flowering and seed formation occur simultaneously in the stands. Under favourable conditions seeds are ripe already 10—15 days after the opening of buds, and they are dispersed by wind, if not collected. In 1946 and 1947 daily observations were carried out with regard to insect activity on the fields. In 1946 85 % of the insects were bees, in 1947 60 %. Only 1—2 % were bumble-bees, and the rest were small flies of different species. According to Ghilarov and Pravdin (39) flies have an important part in pollination at 17° C or lower.

In the germination test conducted in the spring of 1947 it was stated that germination was 85 and 83 % for the seed collected on July 2 and 3, whereas germination was only 54—55 % at the beginning and at the end of the collection period. Ovaries were probably damaged by water accu-

[1]) The number of pollinating insects was counted, depending on weather, twice a day, results are averages of two observations.

[2]) About 60 % of seed heads are open.

mulated in the flower heads, as the germination of seeds with normal appearance was so much reduced.

Table 46 also shows that 50—55 %, at the most, of the weight of the total yield obtained by picking seed heads is pure seed. During a month 980 g. of pure seed was collected from an area of 3 ares. The calculated yield per ha. was 33 kg. Rows were spaced 35—40 cm. apart, and density in rows was 20—30 plants per row meter. The yield of seed does not give an accurate picture of total seed formation, for hand-picking was not efficient enough to prevent seed dispersal by wind.

In 1944—47 seed was also collected from second year stands in different parts of Finland. The highest yields were 20—30 kg. per ha. In most cases, however, the yield was lower than 10 kg. per ha., though seed formation had been abundant.

Hardly any seed was secured from areas with repeated rains at the end of June or at the beginning of July. If seed was collected its germination was very low.

To some extent it was possible to distinguish between seeds with poor and good germination. Germination usually increased with more uniform and brighter green colour. Seeds exposed to rain during seed formation period were brownish or yellowish green. Change of colour from green into brownish yellow did not necessarily indicate decline in germination. Sometimes brownish green seeds, if of uniform size and colour, germinated better than bright green seeds, if seeds were not vernalized (cp. p. 39). If a lot consisted of both dark and light seeds of uneven size germination was 60—65 %, at the highest. Table 47 reports the germination of seed lots at different dates. Seeds were collected in different localities.

Table 47 indicates that the germination of kok-saghyz seed dried immediately after collection in autumn was only about 40—50 %. During winter germination increased being in spring 70—80 %. In some cases germination was determined in the following spring as well. Slight increase occurred only in one case. Generally the germination of unvernalized seed decreased within two years after collection. Effect of vernalization on the germination of kok-saghyz seed has already been discussed (cp. pp. 35—42).

The results show that kok-saghyz seed can be produced throughout southern and central Finland, and undoudbtedly seed can also be produced in northern Finland. However, it is not certain that seed will be secured every year, as seed formation is dependent upon the weather conditions of June and July. According to the results of 1944—47 the failure of seed was only a local phenomenon.

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Table 47. Germination of the seed collected from second year stands at different dates in 1944—1948.

Origin of seed	Germination % (*Jakobsen's* germinator)		
	Autumn	Spring	Spring
1944	**1944**	**1945**	**1946**
Tikkurila	55	70	—
Fiskars	59	82	—
Maaninka	48	64	—
1945	**1945**	**1946**	**1947**
Tikkurila	52	85	—
Fiskars	52	75	61
Hanko	48	81	73
Hartola	40	69	—
Kajaani	48	84	—
Lahti	—	67	—
Leteensuo	—	83	—
Nokia I.	44	80	76
» II.	—	85	—
Peipohja	—	76	85
Pälkäne	—	71	—
Ruukki	—	65	—
1946	**1946**	**1947**	**1948**
Tikkurila (see Table 46)	—	—	—
Fiskars	—	69	46
Hanko	—	81	—
Maaninka	—	74	—
Mikkeli	—	58	—
Nokia I.	—	68	—
Savio	—	60	—
Ylistaro	—	62	—
1947	**1947**	**1948**	**1949**
Tikkurila	—	72	—
Fiskars	—	72	—
Hanko	—	84	—
Maaninka	—	73	—

e. Quality of kok-saghyz rubber prcduced in Finland.

In Finland investigations of the quality of kok-saghyz rubber were only carried out in 1945. The rubber used for investigations was extracted from the roots by means of the method employed in the laboratory at determinations of rubber content. This method is not usually employed for large root lots, for it is expensive owing to the large amount of solvent needed.[1]) The extraction of rubber was conducted by Miss *Elli Auterinen,* partly in the laboratory of Suomen Gummitehdas Oy. at Savio, partly in the laboratory of medicine factory Orion in Helsinki. Evapora-

[1]) This method was used, however, because necessary apparatuses were available, and only a small amount of rubber was extracted for determination of its quality.

tion of all solvent from the mixture of rubber and resin proved difficult, as this mixture became viscous at the final stage of extraction. In order to test the quality of kok-saghyz rubber parallel experimental mixtures were prepared with usual hevea rubber Smoket Sheet, with kok-saghyz rubber I, containing resin, and with kok-saghyz rubber II from which resin had been extracted.

Test mixture.

Rubber	300.0	g.
Zinc oxide	30.0	»
Active soot, German quality	120.0	»
Stearin acid	9.0	»
Antioxidant	—	
Phenyl-naphthylamine	3.0	»
Mercaptobenzothiazoledisulphide	3.75	»
Diphenylguanidine	2.1	»
Sulphur	8.25	»
	476.10	g.

Mixing was, on the whole, successful, but at the end of the operation kok-saghyz rubber I became attached to the roller. 2 mm. plates were vulcanized for 15 minutes and for 30 minutes at 140° C. Tensile strength, elongation, and hardness were tested on these plates. Hevea rubber Smoket Sheet was rolled for 20 minutes before mixing, or for as long a time as kok-saghyz rubber had been rolled at the final stage of solvent evaporation and drying.

Table 48. Quality of kok-saghyz rubber, as compared to that of hevea rubber.

Vulcanized for 15 min. at 140° C	Smoket Sheet	Kok-saghyz rubber I	Kok-saghyz rubber II
Tensile strength kg./cm²	192	133	186
Elongation %	389	576	505
Modulus 450 %	—	84	154
Tensile product $\left(= \frac{\text{Tensile} \times \text{Elongation}}{100}\right)$	745	766	940
Hardness sh°	69	65	60
Tensile strength kg./cm²	173	130	183
Elongation %	343	531	505
Modulus 450 %	—	97	150
Tensile product	593	690	922
Hardness sh°	68	68	60

The vulcanite of kok-saghyz rubber I was porous as all benzole alcohol used as solvent had not evaporated. Owing to resin the vulcanite was tensile, but not elastic. 30 minutes' vulcanization was evidently too long, as results were not so good as with 15 minutes' vulcanization.

The results show that with regard to tensile product kok-saghyz rubber is equal to hevea rubber, even superior to it, when both the tensile strength and the elongation are taken into consideration. With regard to elasticity kok-saghyz rubber was inferior to hevea rubber. It is also possible that the rubber extracted from roots had become oxidized during storage, for the tests were conducted on rubber extracted from roots which had been harvested in 1943 and 1944.

On the basis of investigations conducted in different countries kok-saghyz rubber is generally regarded as being of high quality. Investigations of the quality of rubber have been conducted, for instance, by BOBKOV (19) in U. S. S. R., ESKEW (32) in U. S. A., and FERNANDEZ and NUNEZ (34) in Spain. They have all found kok-saghyz rubber to be equal to hevea rubber. BOBKOV (19) reports the tensile strength of kok-saghyz rubber as 200—215 kg./cm², and the percentage of elongation as 760—800. Canadian *Duff* claims that only 25 % of the Malayan rubber is equal to kok-saghyz rubber, the rest being inferior (154, p. 222). ERICSSON (31, pp. 48—49) gives following values for the quality of kok-saghyz rubber, as compared to hevea rubber:

	Best hevea rubber	Kok-saghyz rubber
Tensile strength kg./cm²	152	162
Elongation %	800	802

A comparison between the tensile product of kok-saghyz rubber produced in Finland (Table 48) and rubber produced in other countries (according to literature) shows that In Finland the percentage of elongation was much lower than in other countries. Reports of investigations, however, do not usually contain formulas of mixtures, which also contribute to tensile product. If less filler should be used in Finland, elongation could be increased at the expense of wear, and values would be approximately the same as those reported in literature.

4. On some other factors affecting the possibilities of producing kok-saghyz rubber in Finland.

In the investigations of the possibilities of growing kok-saghyz, carried out in the years 1943—48, special attention was paid to the development of the plant and to cultural methods under the conditions in Finland. Other factors affecting the production of kok-saghyz rubber, such as economics of cultivation, possibilities and costs of rubber extraction, have not been discussed in this study. A short account of these factors, based on the investigations carried out in other countries, is given on the following pages.

The literature on kok-saghyz received from U. S. S. R. contains very little information as to the field production costs of the plant. Attention is paid to the great expenditure of manpower on kok-saghyz plantings, and cultivation has been mechanized, and methods improved (2; 70; 57; 126). ALTUKHOV (2) reports that kok-saghyz requires 249 mandays per ha. with the usual method of sowing in rows, without mechanization. With sowing in groups the expenditure of labour is only 109 mandays per ha. under similar conditions. In Sweden it is reported that without mechanization kok-saghyz plantings require 1 000 working hours per ha. during the first summer, on weedy soils 700 hours more (148).

Special pains have been taken in Sweden to mechanize the cultivation of kok-saghyz. In 1945 it was estimated that highly mechanized cultivation operations would result in a reduced price per kg. for kok-saghyz rubber, the price probably being 2—4fold over that of hevea rubber. Without mechanization the price will be 6—12 times that of hevea rubber. In these calculations the estimated yield of first year roots was 4 000 kg. per ha., and the yield of rubber 68 kg. per ha. Also the value of technically usable inulin was taken into consideration in these calculations (6, p. 276).

In U. S. A. where the economics of production also received attention it was stated that at peace time kok-saghyz rubber will not be able to compete with hevea rubber owing to high labour requirements and low yields of rubber per ha. (133, p. 181). But kok-saghyz has been found to be of importance at times of crises, such as war, when the importation of hevea rubber into the countries of temperate zone was impossible. Similar results have been achieved in many other countries (cp. pp. 8—15).

Following methods have been tested in factory-scale extraction of rubber from roots (102).

1. *Mechanic means* for breaking tissues and random separation of root mass, e. g. by centrifuging it into fractions containing more or less plant debris.

2. *Chemical means*, such as boiling the raw-material in dilute caustic to destroy plant tissues.

3. Plant tissues are broken by means of *fermentation* and *rotting processes* caused by *bacteria* and *fungi*. In this case inulin, however, cannot be stored.

In U. S. A. a factory-scale method of extracting rubber from roots was developed, based entirely on mechanic operations. Some Russian kok-saghyz experts became familiar with this method and they admitted that it was simpler than any of the methods employed in U. S. S. R. (133, pp. 138—140). If rubber is extracted from roots by means of fermentation and rotting processes caused by micro-organisms, extraction can be carried out already in the field. In U. S. S. R. KIUPT (55) tested this method. He rotted fresh root mass in pits dug in the soil and added some dung and water to it in order to hasten the disintegration process. He also experimented with many antiseptic substances in order to prevent the activity of some rubber-decaying fungi.

Extraction methods must be considered fairly simple, and in comparison with the costs of cultivation, costs from extraction, according to calculations made in U. S. A., are low (133, p. 155). It is evident that the advisability of growing kok-saghyz is in the first place dependent on cultivation costs.

Cultivation tests in 1943—47 showed that it is possible in Finland to produce rubber which in regard to quality is comparable to hevea rubber. It is, however, evident that as long as expenditure of labour on kok-saghyz plantings is great and yields per ha. low, cultivation of kok-saghyz is of no importance in Finland, except at times when importation of hevea rubber is impossible.

The annual demand for raw rubber is in Finland about 2 500—3 000 tons. In addition, large amounts of rubber products are imported into Finland. For instance, in 1938 the value of imported rubber products was 1 milliard Finnish marks (162, pp. 172—176). If, at a time of rubber shortage, 2 500 tons of raw rubber should be produced in Finland, and if the average yield of fresh roots from second year stands were estimated at 3 000 kg. per ha. with 3—3.5 % rubber content, yielding about 100 kg. of rubber per ha., an area of 50 000 ha. would be needed for kok-saghyz cultivations. It is probable that at times of crises it would be possible to do with smaller amounts of rubber for some time.

By exploiting the results achieved in these investigations, it should be possible to double the yield of rubber under favourable conditions. In this case the necessary area would be 25 000 ha. By way of comparison, it may be mentioned that the area of contract growing of sugar beets in southern Finland is now about 6 500 ha.

Though kok-saghyz, owing to high cultivation costs, can nowhere compete successfully with other crop plants there are possibilities of reducing the costs. Mechanization and improved cultural methods are necessary for such reduction. If, in addition, plant breeding and improvement result in higher yields and in higher rubber content of roots it is possible that kok-saghyz will gradually develop into a plant able to compete with other crops in the temperate zone, at least at times presenting difficulties for the importation of hevea rubber.

Summary.

The purpose of the investigation was to elucidate the possibilities of growing kok-saghyz, and especially to find suitable cultural methods for Finnish conditions. The following conclusions have been drawn from the investigations carried out during the years 1943—48.

1. Kok-saghyz thrives in Finland up to the polar circle (66° N. L.) on mineral soils with high organic content and in good farming condition. For peat soils the material of investigations was very scarce, and further investigations should be conducted to determine their suitability for kok-saghyz.

2. The best results were secured from dense (30—90 plants per row meter) spring sowings. Tests with seedling stands and vegetative propagation were not successful. Vegetative propagation was tested both as spring and autumn plantings, but only about 10 % of the planted root cuttings took roots in the field. Crown cuttings taken from roots lifted and topped early in spring resulted in yields of rubber equal to those obtained from field sowings. The possibilities of using this method, however, are limited.

3. In vernalization and the dates of sowing experiments the best results were secured from stands sown with vernalized seed early in spring. Vernalization increased the germination of native seed considerably, in some cases from 47 % to 96 %, whereas only the rate of germination was increased for the seed imported from Germany. Yet germination tests in 1944—47 with the seed received from Germany resulted in better viability for vernalized seed kept in storage dry (at 14—18° C), as compared to untreated seed. Vernalization of 40—50 days resulted in the highest increase in the germination of native seed.

4. Dates of harvesting experiments for first year stands resulted in the best yields for harvestings done when more than 140 days had passed from sowing, and above-ground parts were so wilted that the relation between the weight of rosettes and the weight of roots was lower than 1.5. By this time the accumalation of rubber in the roots was terminated. In southern and central Finland the best time for harvesting was mid-October or later.

5. The investigations showed that under favourable conditions and with proper cultural techniques 6 000—7 000 kg. of roots per ha. can be secured from first year stands in southern and central Finland. Average rubber content of dry matter of roots will be 7.9 %, rubber content of fresh roots 1.8—1.9 %, and the yield of rubber about 130 kg. per ha.

6. For experimental fields the *average* yields from first year stands in different years were: 1 870—3 530 kg. (maximum yield 7 890 kg.) of roots per ha., 31—68 kg. (maximum yield 142 kg.) of rubber per ha., dry matter content of roots 24.1—26.0 %, rubber content of dry matter 5.5—7.5 %, and rubber content of fresh roots 1.4—1.9 %.

7. Kok-saghyz plantings wintered better in cold than in mild winters. Dense stands survived best.

8. The yields obtained from dense kok-saghyz stands in the years 1946—47 indicated that it is advisable to harvest kok-saghyz roots in the second summer of growth. Harvesting must be done after seed formation at the beginning of dormancy when above-ground parts are so much wilted that the relation between the weight of rosettes and the weight of roots is between 1.5 and 1.0. By this time the rubber in the old cortical tissue has not been sloughed off yet, and the accumulation of rubber in the tissue is terminated. In southern and central Finland the best time for harvesting was the end of July and the beginning of August. If, for some reason, it is impossible to harvest the roots at the proper time, or if stands are weakly developed, it is advisable to do the harvesting in autumn.

9. With proper cultural techniques and under favourable conditions 6 000—7 000 kg. of roots per ha. can be secured from second year stands in southern and central Finland. Average rubber content of dry matter of roots will be 13.5 %, rubber content of fresh roots 3.5—4.0 %, and yield of rubber about 230 kg. per ha.

10. From experimental fields the *average* yields from second year stands in different years were: 1 210—4 480 kg. (maximum yield 7 620 kg.) of roots per ha., 31—158 kg. (maximum yield 231 kg.) of rubber per ha., dry matter content of roots 22.6—28.0 %, rubber content of dry matter 11.2—12.8 %, and rubber content of fresh roots 2.6—3.7 %.

11. Production of kok-saghyz seeds was found to be possible in Finland. The best yield of seed was secured from second year stands during June and July.

12. With regard to quality, kok-saghyz rubber was comparable to hevea rubber.

13. The methods employed at the present in the cultivation of kok-saghyz result in so high costs as to justify the cultivation only at times when importation of hevea rubber from abroad is difficult or impossible.

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Selostus.

Kumivoikukan viljelymahdollisuuksista Suomessa

vuosina 1943—1948 suoritettujen tutkimuksien perusteella.

HILKKA SUOMELA.

Maatalouskoelaitoksen kasvinviljelysosasto, Tikkurila.

Tutkimuksen tarkoituksena oli selvitellä kumivoikukan (*Taraxacum koksaghyz*) viljelymahdollisuuksia Suomen olosuhteissa lähinnä sopivien viljelyteknillisten menettelytapojen löytämiseksi. Erikoisesti kiinnitettiin huomiota kasvin kehitykseen, juuri- ja kautsusatojen suuruuteen ja niihin vaikuttaviin viljelyteknillisiin seikkoihin.

Tutkimusaineistona olivat pääasiassa Tikkurilassa Maatalouskoelaitoksen kasvinviljelysosastolla vuosina 1943—48 suoritetut kumivoikukan viljelykokeet, jotka käsittivät paitsi erilaisia kenttäkokeita myös laboratoriokokeita kumivoikukan siemenen itävyydestä, jarovisoinnista ja orastumisesta. Lisäksi käytettiin tutkimusaineistona eri osissa Suomea 60. ja 67. leveysasteen välillä sijainneita 1—10 aarin suuruisia havaintoviljelyksiä, joiden lukumäärä oli vuosittain 17—49 (katso karttaa, s. 26).

Kenttäkokeissa vuosina 1943—48 kasvia viljeltiin käyttämällä pääasiassa riviinkylvöä siemenestä suoraan peltoon. Lisäksi kokeiltiin myös kasvustojen perustamista istuttamalla taimista ja vegetatiivisesti juurenkappaleista lisäämällä. Erikoisesti tutkittiin jarovisoinnin, kylvöajan ja juurien nostoajan vaikutusta sadon suuruuteen. Nostoaikakokeiden yhteydessä seurattiin myös juurien kuiva-aineen ja kautsupitoisuuden muutoksia kasvin eri kehitysvaiheiden aikana yksi- ja kaksivuotisissa kasvustoissa.

Tutkimustulosten matemaattisessa käsittelyssä käytettiin varianssianalyysiä.

Suoritettujen tutkimusten perusteella voidaan esittää seuraavaa:

1. Kumivoikukka menestyy Suomessa napapiirin tienoille asti multavilla, hyvässä kasvukunnossa olevilla kivennäismailla. Turvemaiden osalta tutkimusaineisto oli niin vähäinen, että niiden soveltuvuudesta kumivoikukan viljelyyn Suomessa ei voida tehdä johtopäätöksiä.

2. Parhaat tulokset saatiin tiheistä (30—90 kpl./rivim.) kevätkylvöistä, jotka suoritettiin suoraan peltoon rivikylvönä. Kokeilut kumivoikukkakasvustojen perustamisesta taimista istuttamalla tai vegetatiivisesti juurenkappaleista lisäämällä eivät antaneet myönteisiä tuloksia. Vegetatiivista lisäystä kokeiltiin sekä kevät-

että syysistutuksina, mutta vain noin 10 % istutetuista juurenkappaleista juurtui. Perustamalla kumivoikukkakasvustoja aikaisin keväällä nostettujen ja listittyjen juurien latvakappaleista saatiin kautsusatoja, jotka pystyivät kilpailemaan suoraan peltoon kylvämällä perustettujen kasvustojen kautsusatojen kanssa. Tällä menetelmällä todettiin kuitenkin olevan vain vähäiset käyttömahdollisuudet.

3. Jarovisointi- ja kylvöaikakokeissa saatiin parhaat tulokset jarovisoidulla siemenellä aikaisin keväällä suoritetuista kylvöistä. Jarovisointi lisäsi kotimaassa tuotetun siemenen itävyyttä huomattavasti, eräissä tapauksissa jopa 47 %:sta 96 %:iin, kun sen sijaan Saksasta tuotuun siemeneen jarovisointi vaikutti ainoastaan itämisnopeutta lisäävästi. Kuitenkin todettiin idätyskokeissa vuosina 1944—47, että saksalaista alkuperää oleva siemen säilyi jarovisoituna ja sen jälkeen kuivana varastoituna kolmen vuoden ajan elinvoimaisempana kuin jarovisoimaton siemen samoissa olosuhteissa. Kokeiltaessa eripituisia jarovisointiaikoja kotimaassa tuotetulla siemenellä antoi 40—50 vrk:n pituinen jarovisointiaika parhaan tuloksen.

4. Yksivuotisissa kasvustoissa suoritetuissa nostoaikakokeissa todettiin, että juurien nosto oli edullisinta suorittaa sen jälkeen, kun kylvöstä oli kulunut yli 140 vrk. ja maanpäälliset osat lakastuneet siinä määrin, että lehtiruusuke- ja juurisadon painosuhde oli laskenut alle 1.5:n. Tällöin todettiin kautsun varastoitumisen juureen päättyneen. Etelä- ja Keski-Suomessa oli paras korjuuaika lokakuun puolivälissä ja sen jälkeen.

5. Tutkimukset osoittivat, että käyttämällä oikeata viljelytekniikkaa voidaan Etelä- ja Keski-Suomessa yksivuotisilta viljelyksiltä saada suotuisissa olosuhteissa 6 000—7 000 kg/ha juuria, joiden kuiva-aineen kautsupitoisuus on keskimäärin 7.9 %. Tuoreen juurisadon kautsupitoisuus on tällöin 1.8—1.9 %, jolloin kautsusato on noin 130 kg/ha.

6. Yksivuotisten kasvustojen keskimääräiset satotulokset havaintoviljelyksiltä eri vuosina olivat seuraavat:

Vuosi	Tuore juurisato kg/ha		Kautsusato kg/ha	
	keskim.	maksimisato	keskim.	maksimisato
1943	2 280	3 710	38	66
1944	1 870	4 340	31	87
1945	3 250	5 480	47	99
1946	3 530	7 890	68	142

Juurisatojen keskimääräinen kuiva-ainepitoisuus oli 24.1—26.0 %, kuiva-aineen kautsupitoisuus 5.5—7.5 % ja tuoreen juurisadon kautsupitoisuus 1.4—1.9 %.

7. Kumivoikukka talvehtii paremmin kylminä kuin leutoina talvina. Leutoina talvikausina 1943—44 ja 1944—45 säilyi kasvustosta talven yli keskimäärin 49 %, kun sen sijaan kylminä talvikausina 1945—46 ja 1946—47 vastaava prosentti oli 82. Tiheät kumivoikukkakasvustot talvehtivat useimmiten parhaiten.

8. Tiheistä kumivoikukkakasvustoista vuosina 1945—47 saatujen tuloksien perusteella näyttää siltä, että Suomessa on edullisinta suorittaa juurisadon korjuu vasta toisena kasvukesänä. Kaksivuotisissa kasvustoissa suoritetuissa nostoaika kokeissa todettiin, että juurien nosto oli edullisinta suorittaa siemenen kypsymisen

jälkeen, maanpäällisten osien lakastuttua siinä määrin, että lehtiruusuke- ja juurisadon painosuhde oli 1.5:n ja 1:n välillä. Tällöin ei yleensä vanhan kuoriosan kautsu ollut vielä ehtinyt irtautua juurista ja kautsun varastoituminen uuteen kuorikerrokseen oli päättynyt. Etelä- ja Keski-Suomessa oli paras korjuuaika heinäkuun lopulla ja elokuun alussa. Nostoaikakokeissa todettiin lisäksi, että jos kasvustot olivat heikosti kehittyneitä, niissä tapahtui syksyllä voimakas lisäkasvu, joten oli edullisinta korjata juurisato vasta syys-lokakuussa.

9. Käyttämällä oikeata viljelytekniikkaa voidaan Etelä-ja Keski-Suomessa suotuisissa olosuhteissa saada kaksivuotisilta viljelyksiltä 6 000—7 000 kg/ha juuria, joiden kuiva-aineen kautsupitoisuus on keskimäärin 13.5 %. Tuoreen juurisadon kautsupitoisuus on tällöin 3.5—4.0 %, jolloin kautsusato on noin 230 kg/ha.

10. Kaksivuotisten kasvustojen keskimääräiset satotulokset havaintoviljelyksiltä eri vuosina olivat seuraavat:

Vuosi	Tuore juurisato kg/ha		Kautsusato kg/ha	
	keskim.	maksimisato	keskim.	maksimisato
1944	1 210	3 300	31	79
1945	2 070	3 430	62	111
1946	3 340	4 580	112	174
1947	4 480	7 620	158	231

Juurisatojen keskimääräinen kuiva-ainepitoisuus oli 22.6—28.0 %, kuiva-aineen kautsupitoisuus 11.2—12.8 % ja tuoreiden juurien kautsupitoisuus 2.6—3.7 %.

11. Kumivoikukan siemenen tuotanto Suomessa todettiin mahdolliseksi. Paras siemensato saatiin kaksivuotisista kasvustoista kesä—heinäkuun aikana.

12. Kumivoikukan juurista erotettu kautsu oli laadultaan rinnastettavissa *hevea*-kautsuun.

13. Kumivoikukan viljelykustannuksia nykyisin käytetyillä menetelmillä on pidettävä niin korkeina, että sen viljely toistaiseksi tulee kysymykseen ainoastaan aikoina, jolloin kautsun tuonti ulkomailta on vaikeata tai mahdotonta.