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THE BREEDING OF SWEET LUPINS

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LUPINS have been under cultivation for approximately a thousand years. Up to the previous century the form most frequently grown was as a rule the white lupin (*Lupinus albus*), which is distributed about the shores of the Mediterranean. The plants were used as green manure, and also for human and animal consumption when the bitter principle had been removed by soaking in water.

The white lupin, in spite of its good properties, was not able to gain a foothold in Germany and neighbouring regions such as Poland. Here, in the middle of the nineteenth century, two other species of lupin spread rapidly: *Lupinus luteus* and *Lupinus angustifolius*. These also were used as green manure and, when disembittered, as a feeding stuff.

The value of the lupin lies in its high protein content (30 to 40 per cent), which is equalled in few other crop plants. Its principal disadvantage, the high alkaloid content which made the disembitterment process necessary, has always been troublesome, but accepted as inevitable. Only to sheep could lupins be fed without previous treatment.

At the end of the nineteenth century a new animal disease, named "lupinose," made its appearance in consequence of feeding the grain and straw of yellow and blue lupins to stock. The disease assumed such proportions that considerable limits were set to the cultivation of lupins. Although an intensive study of the disease was made, neither the causal agent nor the actual cause could be determined.

The cause of the lupin's characteristic bitter taste is to be found in the alkaloids. A desire to obtain lupins having a low alkaloid content, or being entirely alkaloid-free, has always been felt.

At the beginning of the present century the alkaloid problem was attacked again and again by a series of workers. It was Roemer in particular who made a study of differences in this respect and who sought for forms with low alkaloid content. In 1924, Prjanišnikov attempted to evolve a chemical method of making tests, and expressed the conviction that it would be possible to detect alkaloid-deficient forms if the number of plants tested was sufficiently large. Baur expressed similar beliefs in 1927. In the course of a lecture he asserted that alkaloid-deficient forms must exist among the ordinary bitter lupins of the present day. It was only a matter of discovering the right method of detecting them. He assumed that the peas (*Pisum sativum*) now in use, which have no bitter taste, possibly emanated from bitter forms.

In 1927 I began to work out a technique for the detection of alkaloid-deficient forms. In the first experiments biological methods were employed, with a view to utilizing the poisonous action of the alkaloids. These methods were not successful.

Next I succeeded in working out a chemical method which appeared to be suitable for dealing with a large amount of material. At the outset it was not known whether entirely alkaloid-free types actually existed. For this reason search was first made for individuals with an alkaloid content reduced by 20 per cent. When these plants had been detected, forms with an alkaloid content lower by 50, 70, 90 per cent and over, became the objective, and such plants also were found.

From some varieties of lupin species I then selected, during the years 1927 to 1931, forms practically free of alkaloids. In order to detect the few alkaloid-free individuals I have studied a total of many million single plants. These individuals have been reproduced throughout the past ten years. Since 1931 reproduction has been in the hands of the Saatgut-Erzeugungs-Gesellschaft (Seed Production Company), Berlin, which not only reproduces the sweet lupins but is also engaged in further breeding work with them. The following varieties are to-day in the market: yellow von Sengbusch's Müncheberg green fodder sweet lupin, and blue von Sengbusch's Müncheberg green fodder sweet lupin.* The white sweet lupin is not yet released for sale.

Such progress has been made with the reproduction of sweet lupins that to-day not only can requirements in Germany be covered, but in other countries also, and in Poland in particular, sweet lupins are being reproduced for sale.

More recently other workers have found alkaloid-free yellow, blue, white and perennial lupins by means of a biochemical method (Laube, Heuser; Ivanov, Smirnova, Fedotov, *Herb. Abstr.* 3. 48. 1933.)

In addition to this most important problem in the breeding of lupins, the discovery of alkaloid-free forms, there were others to be solved.

(1) The elimination of hardness of seed-coat in *Lupinus luteus* and *Lupinus angustifolius*. By suitable drying, together with examination for softness of seed coat, we succeeded in selecting individuals having entirely soft-coated seeds. For the discovery of these forms approximately 20,000 single plants were studied.

(2) Of the utmost importance also is the elimination of the tendency of the pods to shatter, both in *Lupinus luteus* and *Lupinus angustifolius*. In warm harvest weather the shattering of pods may cause a loss of 50 per cent and over. Normally the loss amounts to 20 per cent.

I started the selection of non-shattering forms in 1929. Although I examined several million single plants, efforts were at first unsuccessful. Not until 1935 and 1936 was an individual found possessing completely indehiscent pods (von Sengbusch and Zimmermann). In 1936 and 1937 the descendants likewise proved to have non-shattering pods. We have been able to ascertain that in this strain the character "non-shattering" is based upon the abnormal structure of the pod suture. The sclerenchyma strands, which in normal lupins are separate, are united in the non-shattering form and thus prevent the splitting of the sutures.

We studied altogether considerably over ten million plants before this strain, No. 3535A, was found.

*"Gelbe von Sengbuschs Müncheberger Grünfutter Süsslupine" and "Blaue von Sengbuschs Müncheberger Grünfutter Süsslupine" are the legally protected names of the varieties.

These valuable characters, namely, freedom from alkaloids, soft seed coat, and indehiscent pods, were sought separately ; that is to say, in each case plants with one or other of these characters were selected out of indigenous bitter material. Our task now is to combine these characters with one another, to produce a plant which shall be alkaloid-free and shall have soft seed-coats and non-shattering pods.

In order to ascertain what combinations are possible, inheritance in the separate characters was studied. We were able to prove that all three characters are each based upon a recessive factor, and that there thus exists a very good possibility of combining them rapidly. The freedom from alkaloids in the respective strains rests upon different genes. In the crossing of two strains which are alkaloid-free on the basis of the different genes, the F_1 generation contains alkaloids, the F_2 generation segregates into a ratio of 9 alkaloid-containing : 7 alkaloid-free individuals. One of these sixteen combinations contains both genes for freedom from alkaloids. When crossed with either parent. it gives alkaloid-free forms. These doubly recessive alkaloid-free strains may under certain circumstances be of practical importance. Their alkaloid content might be still farther reduced in comparison with the initial alkaloid-deficient forms. Work on the production of these forms is in progress.

Within another ten years we shall be able to grow an ideal form of the lupin, alkaloid-free, having soft seed-coats and indehiscent pods. For the agriculture of Germany, and of the surrounding countries with similar climatic and soil conditions, the new sweet lupins are a valuable addition to the cultivable plants, for the bitter lupins could not be regarded as full-value crops.

With the discovery of the non-shattering forms new possibilities in the utilization of the lupin have been opened up. The growing of lupins for grain will now receive an impetus, and it will be possible to employ lupins directly for human consumption. By the employment of lupins, with their high protein content, for human consumption there would be ensured a use of their protein four times higher than that achieved in feeding them to animals. They could take a place beside the soybean and the pea.

The new tasks involved in the use of lupins for human consumption are the improvement of grain shape and colour, meal colour and quality, shelling capacity, etc.

All these were and are problems peculiar to the breeding of lupins. In addition to them, however, the breeder is confronted by a whole series of other tasks common to the breeding of practically every cultivated plant.

In the case of lupins grown for grain, seed yield stands in the foreground of interest. Until now it has not been possible to breed systematically for grain yield, because the lupins could not be harvested without loss. With the discovery of the non-shattering forms this task will merit especially close attention.

When lupins are grown for green fodder, whether as the main crop or as a catch crop, green weight is of primary importance. In this direction also there is room for much progress.

In the growing of green fodder lupins, moreover, sowing costs have a certain degree of importance. Through the breeding of small-seeded forms, provided seed

yield remained equally high, one might reduce the seeding rate and therewith the cost of sowing.

Yet another task to be mentioned is that of breeding for resistance to the principal forms of disease. When lupins, grown as a catch crop, are left in the field late into the autumn and there is occasional stoppage of growth, they tend to be heavily attacked by mildew, which reduces to a certain degree their value as a feeding stuff. To what extent the diseases of the lupin may be controlled through breeding cannot yet be foreseen, but nevertheless it will be necessary to deal with this problem also.

The sensitivity of the lupin to lime belongs, perhaps, to the physiological disease group. This sensitivity is most marked in the yellow lupin, less marked in the blue and least in the white lupin. It might be possible to select forms with a lower degree of sensitivity to soil calcium.

A remarkable phenomenon has made its appearance in the course of breeding the sweet lupin. Some of the blue and the white sweet lupins exhibit more or less serious fertility disturbances, but only under unfavourable weather conditions during flowering (dry, warm weather). These disturbances are correlated to slightly reduced yield, compared with the bitter initial material. As nearly all the alkaloid-free individuals selected from these two species, irrespective of the actual source from which they come, exhibit more or less marked fertility disturbances, there may be involved either a pleiotropic action of the gene for alkaloid content or a linkage with fertility-disturbing genes. In the former case it would be necessary to seek new genes for freedom from alkaloids, such as would not exert this pleiotropic influence. In the second case completely fertile alkaloid-free forms might be found among the cross-overs.

The various lupin species are cultivated in different regions. On account of its early ripening the blue lupin is the species, with the exception only of *Lupinus polyphyllus*, that can penetrate farthest north ; and in the north of Europe, therefore, blue lupins are cultivated. Further south (Germany, Poland) yellow and blue lupins are grown side by side. In the Mediterranean region, Hungary and the Balkan States the white lupins flourish. The area devoted to lupin cultivation is considerable in countries other than Germany and Poland, namely, Hungary, Italy, the south of France, Spain, Portugal and Egypt.

	hectares
Poland ..	167,770 for grain, yellow and blue lupins
Italy	330,000 for human consumption, white lupins
Spain	13,350 for human consumption, white lupins
Egypt ..	6,254 for human consumption, white lupins

As we are in possession of yellow, blue and white sweet lupins, within a measurable space of time lupin cultivation will be completely reorganized in favour of the sweet lupin. When that is accomplished, not only will the present-day lupin areas be used to better advantage, but a great increase in the proportion of land devoted to lupin-growing will take place, especially in Mediterranean regions. The sweet lupins will supply a food of high value for human consumption and for animals, and will give

relatively high yields even under the most unfavourable conditions. The white sweet lupin will be of greater importance for all tropical and subtropical regions. To what extent the yellow and blue lupins will penetrate into the white lupin area, and conversely the white lupin into the area of the yellow and blue lupins, future experience will show. It will depend, moreover, upon the results of breeding work still to be done. Thus, for example, the penetration of the white lupin into central and northern Europe is dependent upon the discovery of early forms which can be relied upon to ripen even under unfavourable climatic conditions.

Today the yellow and blue sweet lupins have already made headway beyond the confines of their homeland, Germany, and are being cultivated in surrounding countries. It will require some time yet for the white sweet lupin to spread through the whole Mediterranean region. The yellow, blue and white sweet lupins will undoubtedly be adopted as new crop plants in every country in which climatic and soil conditions permit the growing of lupins.

A special problem is presented in the breeding of oil lupins. In many European countries, especially in the north, we have no suitable oil plants other than linseed and hemp. Most oil plants grow in the tropics and subtropics. There is therefore a demand for new forms which may be grown in central and northern Europe. Baur pointed out that *Lupinus albus* and *Lupinus mutabilis* might be suitable for the purpose if their oil content could be increased from 10 per cent to approximately 15 or 16 per cent. In accordance therewith I have been engaged since 1932 in the evolution of a technique for the rapid determination of oil content, and have begun to select individuals of *Lupinus albus* having a high content of oil.

Laube, of Petkus, referred to *Lupinus allus* in 1933 as " the German soybean." The Russians have taken up the same problem and have also started to breed oil lupins.

The final objective of oil lupin breeding must be the production of an alkaloid-free oil lupin, of which the remaining parts—after the oil has been extracted—may be used as a feeding stuff without any further treatment. The oil lupins available up to the present time, probably without exception, have been selected from bitter material.

Of the practical importance of the oil lupin no judgement can be formed for the present, as no information concerning its yield of oil per unit area is yet available. It will probably be very much easier to produce oil lupins for the Mediterranean regions, where the time of ripening constitutes no problem. In central Europe, however, an oil lupin must be required to ripen uniformly early. This combination is hard to find.

It will be some years yet before we shall be able to see clearly in respect to the oil lupin and its economic importance.

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