SOME NOTES ON THE LINACEAE.

THE CROSS POLLINATION OF FLAX.

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Whilst testing a large number of species of Linaceae for cyanophoric glucosides during the past three years, it was observed that those species carrying white, blue or red flowers were more or less richly cyanophoric whereas the yellow flowered species, which for the most part exhibit an entirely different habit, failed to yield hydrogen cyanide and seemed to be devoid of cyanogenetic enzyme. During 1913 observations were made on a larger number of both blue and yellow flowered species and the previous observations have been confirmed. (Studies on Enzyme Action, xviii, *Royal Soc. Proc.*, B, vol. lxxxv, 1912.)

That the absence of cyanophoric glucoside and its enzyme is in any way correlated with the presence of the yellow pigment cannot be stated, but the fact that both glucoside and enzyme are absent from yellow flowered varieties led to the attempt being made to produce a yellow flowered flax containing glucoside or enzyme, or both[1], so as to throw light upon the question of the inheritance of Chemical Characteristics, and from this point of view the work has been extended. The present circumstances, however, are likely to cause a break in this work, and it is therefore considered desirable at this stage to place on record the observations which have been made.

[1] The most complete information relating to hybrid flaxes appears to be contained in Graebner's *Synopsis der Mitteleuropäischen Flora* but, with the exception of the uncertain cross *L. salsoloides* × *alpinum*, the only cases referred to, namely *L. perenne* × *austriacum* and *L. narbonennse* × *usitatissimum*, both due to Kolreuter (*Nov. Act. Acad. Sci. Petrop.* i. p. 339), do not afford the examples required.

The flowers of all the flaxes so far examined—numbering more than sixty—are hermaphrodite and although the flowers are slightly protandrous, when attempting to cross-fertilise it was found necessary to emasculate the buds.

The petals fall very readily when the buds are opened for the removal of the stamens. This of course deprives the stigmata of their protection, but seems to be in no way detrimental. It was found convenient therefore to discard the usual method of emasculation for the following. When the bud is advanced to within a day or so of opening, the tips of the petals were taken between the finger-tips and the corolla removed by a sudden jerk, thus exposing the stigmata and at the same time effecting the complete removal of the stamens. The stigmata, which at this stage are not receptive, apparently suffer no more by this somewhat rough treatment than by the more careful method usually employed; the bag by which they are covered affording sufficient shade and retaining the necessary moisture for their normal development, and we were able to convince ourselves by numerous trials that the stigmata were not pollinated by the removal of the stamens by this method[1].

Whilst testing the efficacy of this rough method of emasculation, a large number of flowers were so treated and kept covered without being pollinated. In every case the stigmata dried off and no sign of capsule development could be detected. This fact is recorded as showing that in the three species so treated, namely *L. perenne*, *L. flavum* and *L. maritimum*, seed is not normally produced parthenogenetically.

The flowers of some species of Linum, like those of the primrose, have styles of two different lengths, i.e., are dimorphic. This dimorphism is considered to be an adaptation favouring cross fertilisation and has been referred to by Darwin and others. Darwin[2] records that *L. perenne* yields no seed as a result of illegitimate pollination: we have not been able to confirm this but have found that when using this species of Linum about 30 per cent. of the short styled flowers produced seed capsules when "covered" owing to the pollen dropping on to the stigmata and very few of the long styled flowers set seed under the same conditions of isolation. It is probable that both types

[1] After some practice it was found possible to use this method of emasculation successfully with long styled as well as short styled flaxes. Some care has to be exercised however in selecting buds in which the style has not become too elongated.

[2] *Forms of Flowers*, 1892, p. 89.

are capable of self-fertilisation because we have found that all flowers similarly treated and artificially pollinated by pollen from the flowers of the *same plant* set seed. This inference is supported further by the manner in which *L. perenne*, both short and long styled, set seed when "bagged" for the purpose of providing a supply of pollen for the trials we have made. In addition we have found that *L. perenne* ♀ carrying blue flowers with short styles when pollinated by *L. perenne* ♂ carrying white flowers with short styles produced seed normally and presented no difference from the case where a short styled blue flowering *L. perenne* ♀ was pollinated by a long styled *L. perenne* ♂ having white flowers.

The first attempt to effect a crossing between a Linum which contains glucoside and enzyme and one which does not—the main object of this work—was made in 1913 with *Linum monogynum* ♂ (Forster), a native of New Zealand, which is not dimorphic and *Linum flavum* (Linn.) ♀, a yellow flowered perennial plant which is dimorphic. Although tried repeatedly this cross seemed impossible to effect. The reciprocal cross, *L. flavum* ♂ and *L. monogynum* ♀ was however found to be successful, the ovaries of *L. monogynum* developed normally and each of the three capsules finally obtained contained three or four seeds; but this small number of seeds per capsule seems to indicate that fertilisation is difficult, and although the ten seeds obtained appeared to be quite normal not one of them germinated.

Linum maritimum, a dimorphic, tall yellow flowered species, was pollinated by *L. perenne*—both the blue and the white varieties—but without success; nor was the reciprocal cross any more successful. Concurrently with these attempts to hybridise the yellow flowered species, others which were in flower were also tried. It has been mentioned already that the white and blue varieties of *L. perenne* cross very readily, and this gave rise in the F_1 generation to plants bearing large pale blue flowers veined by darker blue. This fact is interesting as it may throw some light on the origin of some of the numerous varieties of *L. perenne* which now exist. *L. perenne*—both the blue and the white—was pollinated by *L. grandiflorum*, the common red species of the garden, but although every care was taken to use fresh pollen and to pollinate only receptive stigmata, no fertilisation was effected.

L. monogynum was pollinated by *L. grandiflorum* and all the ovaries commenced to swell, but before they were half developed a number of them had fallen and only a few matured: these on being opened proved to be seedless. To explain the cause of this growth it seems necessary

to assume that the pollen lived and gave some stimulus to the carpels but failed owing to some morphological or chemical obstacle to reach the ovules. Such stimulation of the ovaries without fertilisation is known to occur in other orders of plants.

In 1914 renewed attempts were made to fertilise the yellow flaxes by pollen from flaxes containing enzymes and glucosides. In the case of *L. arboreum* (Linn.), a species which resembles *L. flavum* (Linn.) but differs by its shrubby habit, more woody stem and its glaucous leaves, two hundred trials were made with pollen from *L. monogynum* (Forst.), upwards of one hundred trials with pollen from *L. narbonennse* (Linn.), fifty trials with *L. austriacum* (a variety of *L. perenne*) and one hundred and fifty trials with blue flowering *L. perenne*, and in no case was any positive result obtained. Although the stigmata remained perfectly healthy no swelling of the ovaries took place. Attempts were made again to effect a cross between *L. flavum* (Linn.) and *L. monogynum* (Forst.), but in none of the one hundred and fifty trials made did fertilisation of the *L. flavum* take place and fifty attempts to effect the reciprocal cross, *L. monogynum* ♀ with *L. flavum* ♂, only gave one capsule containing one seed which did not germinate. Our efforts to fertilise *L. narbonennse* by *L. monogynum* and by *L. arboreum* were no more successful and more than one hundred trials to pollinate blue *L. perenne* by *L. arboreum* and by *L. monogynum* were equally unsuccessful. Similarly when white flowering *L. perenne* and *L. austriacum* were employed for pollinating *L. arboreum* no fertilisation ensued. The pollination of *L. monogynum* by *L. arboreum* appeared at first to have been successful; most of the two hundred trials made resulted in early swelling of the ovaries and capsule development set in, but after about three weeks all but three capsules had dropped off and of those which remained one contained no seed, one contained ten seeds and the other three seeds. From these eleven plants have been raised, the foliage of which resembles that of *L. monogynum* both in general appearance and in containing both enzyme and glucoside associated with that species. So far these plants have shown no signs of flowering, and in this respect they differ from seedlings of *L. monogynum* raised at the same time.

Some two hundred trials were made to secure a cross between *L. monogynum* ♀ and *L. narbonennse* ♂ and of these quite half exhibited swelling and the capsules remained on the plant for some time. Finally however only three capsules remained and these yielded two and three seeds in each. From these only three plants could be

raised which again only differ from *L. monogynum* in that they show no signs of coming into bloom.

In addition to these experiments with isolated plants observations have been made of the character of the plants raised out of doors on a number of plots where considerable quantities of different varieties of flax have been grown. These variety trials of commercially grown seed have been conducted during several years and have afforded an opportunity for watching any changes which might occur in the character of any particular variety.

It has been mentioned already in a previous publication (*loc. cit.*) that in certain flax-growing districts the opinion prevails that flax is unstable, readily losing certain of its characters when grown repeatedly in those regions. It is stated for example in certain parts of Central Russia that besides changes in habit, the colour of the flower changes. Little information of a reliable character bearing on these points being available and in view of their importance in connection with attempts which have been made concurrently with this work to isolate improved strains of flax for commercial purposes, it was decided to make use of the material at hand to test the truth of these statements.

On many of the flax plots grown in 1912 it was observed that a small proportion of white flowering plants accompanied those bearing blue flowers, whereas on other plots the plants were either entirely blue or entirely white flowering. When the seed from the white flowering plants accompanying the blue were collected separately, without "bagging," and sown in 1913, plants bearing white flowers only resulted, and seed collected from the blue flowering plants gave only blue flowers. Examples of this kind were met in the case of *L. usitatissimum* from Vologda, Pskoff and Holland, and also in the case of the so-called varieties of this species, namely *L. chamissonis* from Valencia, *L. multiflorum* from Heidelberg and several others.

Besides this difference in the colour of the flowers there was noticed also with some of the varieties grown a difference in the depth of the colour of the flowers, some being of a darker shade of blue than others which occur alongside on the same plot. *L. floccosum* furnished one example of this kind, and the large seeded variety of linseed which is imported from N. Africa another example, where a difference in the intensity of colour extends not only to the flowers but also to the foliage of the plant; some bearing pale green, others dark green leaves.

Seed of *L. pallescens* obtained from Madrid gave an uniform crop of pale blue flowering plants in 1912 when grown at The John Innes Institute at Wimbledon, but the seed saved from that crop and grown at the South-Eastern Agricultural College at Wye during 1913 gave rise to a mixed crop; some few plants bearing white flowers and the others pale blue flowers similar to those of the 1912 crop. The seed saved from the white flowering plants gave in the next year (1914) mostly white flowering plants, accompanied by a few bearing pale blue flowers. The seed saved from the pale blue flowering plants gave in 1914 only pale blue flowering plants. Other instances of change in the colour of flax flowers when grown in the open year after year under ordinary conditions have also been observed, an interesting one being afforded by *L. humile*, the seed of which was obtained from the Botanical Gardens at Madrid. This gave a mixed crop when grown in 1912 of dark blue, white and pale blue flowering plants. The seed saved from the dark blue flowering plants gave in 1913 plants bearing dark blue flowers only, and the seed saved from the white flowering plants gave only plants with white flowers in 1913. The seed saved from the pale blue flowering plants however gave a crop which consisted of pale blue, white and dark blue flowering plants in 1913. When the seed was saved and sown separately in the next year (1914) it was again found that seed from the dark blue flowering plants gave plants carrying dark blue flowers, and seed from the white flowering plants gave plants carrying only white flowers, whereas the seed saved from plants which had pale blue flowers again gave rise to plants having white, pale blue and dark blue flowers. In 1913 selected plants of *L. humile* were "covered," and the seed sown in 1914 when it was found also that the white came white, the dark blue came dark blue, and, as with the plants that were not "covered," the pale blue flowering plants gave rise to plants bearing dark blue, white and pale blue flowers.

These observations appear to afford an instance of the segregation of allelomorphic characters, expected when a hybrid is propagated from seed. This is of particular interest in view of the fact that both *L. usitatissimum* and *L. humile* very readily self-pollinate, and although not themselves dimorphic possess styles apparently as long as a long styled form in a dimorphic species.

The flaxes are sometimes regarded as "selfing" so readily that there is small chance of cross-pollination being effective. It seems quite clear however from the foregoing observations that this is not always the case and does not apply to the varieties of *L. usitatissimum* commonly

grown, and this view receives support also from the fact that dimorphism occurs among the species of Linum. It is noticed that the pollen is somewhat adhesive in character and is produced only in relatively small quantities, and it seems highly probable that the crossing which takes place is almost entirely caused by the insects which may be observed visiting the flowers freely.

The attempts being made to isolate improved strains of flax for commercial purposes have been referred to already. These are being conducted at Wye under the auspices of the British Flax and Hemp Growers' Society, and were commenced in 1912.

Flax is grown very extensively both for the seed it bears and for the fibre which is contained in the stem. The value of a flax crop when grown for the fibre depends mainly upon uniformity in height over the whole crop, tallness and branchlessness of the individual stems and upon the quantity of fibre they bear—the seed obtained from the crop being in this case of minor importance. In the case of a flax crop grown for seed its value depends mainly upon the quantity of seed produced and upon the oil-content of the seed obtained—the straw in this case being of relatively little value is frequently disregarded.

The sowing seed sold commercially for these purposes usually gives rise to crops which exhibit certain marked irregularities, and this is noticeable more particularly when flax is raised for fibre production. Generally speaking such crops are composed of tall and short growing plants, some of which carry much and some little seed, whilst many may be observed which exhibit a marked tendency to branch at the base instead of giving long single branchless stems.

The object has been to obtain from such mixed seed which usually comes on the market and from other sources some selected strains of seed more suitable for the economic production of fibre on the one hand and of seed rich in oil on the other.

With regard to raising improved strains for the latter purpose the work has not yet proceeded far enough to warrant anything definite being said, most attention, up to the present, having been devoted to exploring the possibilities of improving the flax fibre crop.

In the first year of this work (1912) the samples of seed which one of us had collected for the purpose in 1911 from particularly good flax fibre crops in various parts of Russia, Holland and Belgium, and also certain trade samples were grown at The John Innes Institution, where we were able to profit by the example of work of a similar nature which

was already proceeding at that Institution. From certain of these trial plots a number of plants were selected for tallness of branchless stem and absence of tillering, and these were "covered" separately. Some additional plants were selected from some of the same plots on account of their shortness of stem, and these were also "covered" separately. Under these circumstances of isolation seed set abundantly.

In the following year, 1913, the seed from the "covered" selected plants were sown at Wye, each seed being sown separately one foot apart in rows, which were also one foot apart so as to give each plant a full opportunity for displaying its true character. It should be mentioned also that throughout this work a method of labelling has been adopted which has maintained the identity of each of the plants originally selected.

When the plants raised in this manner were about to come into flower a similar selection was made again, and of the plants raised from selected tall parents only those plants were "covered" which had not tillered and which possessed relatively tall single stems—the measurements being made in every case from the ground level up to the lowest branch on the stem. In the case of the plants derived from selected short parents only short plants were selected and "covered." It appeared evident at this stage of the work that if tall plants and short plants are selected from one and the same crop, and these are properly "covered," and the seed resulting from the selfing of the covered plants is sown, tallness generally characterises the plants derived from tall parents and shortness those from short parents[1].

In 1914 a similar procedure was followed with regard to sowing the seed obtained from the "covered" plants of the previous year, and it was noticed again that plants selected for tallness and for shortness breed true to those characters—an average difference of about twelve inches in the height from the soil level to the first branch being observed between those plants resulting from a repeated selection for tallness and those repeatedly selected for shortness.

With the object of ascertaining how far these efforts to eliminate tillering had been successful and how far the general height of the crop was likely to be increased, reference plots were arranged alongside the plots of twice selected flax, upon which some of the various samples of seed originally employed in 1912 were grown under similar conditions regarding distance apart.

Upon making a comparison of the crop raised from the originally

[1] *Vide Journ. Agric. Soc.* England, 1913, LXXIV, 140.

imported seed and the corresponding crop raised from the selected seed, it was at once apparent that an increase in the height had been brought about by selecting for tallness and the crops from the selected seed presented a greater degree of uniformity. The actual amount of the increase was found to vary with the different samples. In the case of one of the samples brought from Pskoff and another from the Province of Livonia an increase of nearly ten inches was manifest. In other cases the increase was not so marked, while with seed procured from the region of Minsk no increase in the height was noticeable.

With regard to tillering our efforts have not proved so successful. The accompanying figures represent some of the results obtained and are arrived at by taking some five hundred plants at random from the parent plots and a similar number from the selected plots, and counting those which had tillered and those which had not at the time of flowering.

Reference name of seed	Percentage of plants which tillered: Parent seed 1911 grown 1914	Percentage of plants which tillered: Selected seed grown 1914
Dutch II	87 per cent.	60 per cent.
,, III	93 ,,	70 ,,
Pskoff I	90 ,,	56 ,,
,, III	95 ,,	71 ,,
Livonian I	86 ,,	72 ,,
,, II	—	72 ,,
Vologda	89 ,,	78 ,,
Dedoviezy	89 ,,	70 ,,
Rsheff	96 ,,	66 ,,

Although the proportion of plants which tiller to those which do not has been reduced considerably, it appears that local conditions of soil play such an important part in conditioning this manner of growth that it would appear doubtful whether much more can be done in this direction.

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