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BRASSICA CROSSES.

By

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BRASSICA CROSSES.

By ARTHUR W. SUTTON, F.L.S., V.M.H.

IN 1899 I was attracted to the study of crosses among species and varieties of Brassicas by a statement in one of the leading agricultural journals that certain types mentioned by the writer do not hybridize naturally, and therefore can be grown in close proximity to each other without fear of destroying the highly selected forms which the seedsman is at so much pains to keep true.

As experience gained during many years' association with practical seed-growing convinced me that the statement was incorrect, I decided to put the matter to a practical test in order to place on record the results obtained, and to show which species and varieties of *Brassica* would intercross and which would not.

In the first experiments, begun in 1900, the varieties of *Brassica oleracea*, L., shown in figs. 1 to 9 (Pl. 1), were planted side by side so that cross-fertilization might take place wherever such was possible. (For names of these varieties see list on page 10).

The seed saved from these plants gave rise to an extremely heterogeneous collection of nondescript forms, few or none of which were true to the female parental type. Various types, however, were noticed which there was every reason to believe would, if it were possible to perpetuate them, become valuable additions to the economic plants of the farm or garden. From these the forms represented in figs. 10, 11, 12, & 13 (Pl. 2) have been fixed, and come fairly true from seed.

In a later season the experiment was repeated with the addition of varieties of Turnips (*Brassica Rapa*, L.), Swedes (*Brassica campestris*, L., var. *Napobrassica*, DC.), and non-bulbing oil-yielding Rape (*Brassica campestris*, var. *oleifera*, DC.).

Instead, however, of all being planted in one large patch, they were arranged in small isolated groups of seven plants each. Two of the plants were of one variety, and round them were placed five of another kind. In this manner about twenty such double combinations were arranged and the seed saved and grown.

A large collection of mongrel plants was obtained; the results were entirely in accordance with my previous experience, and proved that while no variety derived from *Brassica oleracea* was affected by the pollen of Rape, Swede or Turnip, and *vice versa*, yet all the types of *B. oleracea* would freely intercross between themselves, and this was equally true of many varieties of Turnip, Swede, and Rape.

Hitherto I had been content to note such species of *Brassica* as would intercross when planted in close association, but looking over the plants raised in the last experiment with Professor Percival of University College, Reading, we concluded that the experiment would be far more complete if a series of carefully controlled artificial crosses were undertaken in order to ascertain whether some

Brassica Crosses.

of the species or varieties which had not naturally intercrossed in the previous experiment, might do so when the flowers were artificially pollinated.

The Brassicas selected for this experiment are shown on Plate 3, and consist of :—

- Fig. 16. Colza Rape (*Brassica campestris*, L., var. *oleifera*, DC.). Resembles the Swede in its glaucous leaves, which when young are hispid, but its flowers are bright canary-yellow.
- „ 17. Ragged Jack Kale. A plant resembling in general character the Colza Rape and Asparagus Kale, but with lacinated leaves. } Flowers bright canary-yellow.
- „ 18. Asparagus Kale closely allied to Colza Rape.
- „ 19. Kohl Rabi (*Brassica oleracea*, L., *caulo-rapa*). } The flowers of these three types are almost alike and of a pale yellow colour.
- „ 20. Thousand-headed Kale (*Brassica oleracea*, L., *acephala*).
- „ 21. Drumhead Cabbage (*B. oleracea*, L., *capitata*).

Swede Turnips, viz. :—

- „ 22. Purple-top Round White-fleshed (*Brassica campestris*, L., var. *Napo-brassica communis*, DC.).
Flowers bright canary-colour.
- „ 23. Purple-top Round Yellow-fleshed } *Brassica campestris*, L., var. *Napo-*
- „ 24. „ Tankard „ } *brassica Rutabaga*, DC.
Flowers pale buff-colour.

Turnips, viz. :—

- „ 25. { Green-top Yellow-fleshed } ? *Brassica Rapa*, L.
 { Purple-top Yellow-fleshed }
Flowers pale buff-colour.
- „ 26. Purple-top White-fleshed } *Brassica Rapa*, L.
- „ 27. Green-top White-fleshed }
Flowers bright canary-colour.

From this point I had the advantage of the able assistance of Professor Percival, who personally emasculated the blooms and applied the desired pollen.

The chief objects we had in view were :—

- (1) To determine which varieties of *Brassica* would cross with each other, and whether the plants of the first filial generation (F 1) were fertile or sterile.
- (2) To draw such conclusions as might be possible from results thus obtained concerning the origin of the principal distinct types of Swedes and Turnips, and more especially to ascertain whether the White-fleshed and Yellow-fleshed Swedes had a common origin, as also the White-fleshed and Yellow-fleshed Turnips.

- (3) To ascertain whether a Yellow-fleshed Turnip similar to those termed "Hybrid Turnips" by some seedsmen and farmers could be produced by crossing the Swede (*Brassica campestris*, L., var. *Napo-brassica*, DC.) with the White-fleshed Turnip (*Brassica Rapa*, L.).
- (4) Incidentally we wished to obtain light upon the relationship of the different cultivated forms of *Brassica*.

Arising out of these experiments it became evident that the results had a definite bearing on Mendelian phenomena.

The plants used for crossing were grown in the open trial grounds, but flowers selected for fertilisation were very carefully emasculated before the stamens were ripe, and enclosed in small paper envelopes. The pollen was obtained only from flowers which were allowed to open inside close-fitting paper bags to prevent the possibility of stray pollen becoming mixed with that which was to be used in the experiments.

Many apparently unopened flowers were found to be useless for our purpose on account of the attack of minute larvæ of species of *Meligethes* and *Cecidomyia*, which had fed on the immature pollen in the anther lobes and scattered some of it in the inside of the flowers.

In addition to the greatest care in emasculation and in the exclusion of insects large and small, each stigma was examined with a Coddington lens to make certain of its clean state before the application of the pollen.

Over 80 distinct crosses were attempted.

Taking into consideration the results obtained from them, they may be arranged in three groups, viz:—

Group I. Crosses from which no seed was obtained.

„ II. Those plants from which seeds were produced but the plants raised from them proved self-sterile.

„ III. Those plants from which seeds were obtained and the plants from which were quite fertile among themselves.

Group I.—No seed resulted from the pollination of

Cabbage Thousand-headed Kale Kohl Rabi	}	with	{	Swedes, Turnips, Colza Rape, Asparagus Kale, Ragged Jack Kale,
--	---	------	---	--

or the reverse pollinations.

In some instances the pollen appeared to act as a stimulus to the growth of the pericarp of the fruit, the pods growing to the normal size or even larger, but the ovules were abortive.

Group II.—To this group belongs the cross

♂		♀			♂		♀	
White-fleshed				on	Swede,	and its reciprocal	Swede on	White-fleshed
Turnip								Turnip,

which proved remarkable in many ways.

When the Swede is fertilized by the Turnip, that is, when the Swede is made the seed-bearer, the seeds obtained are abundant. They are large and black-coated like those of the typical Swede, and contain embryos which grow vigorously into fine healthy plants.

In the reciprocal cross, that is, where the Turnip is fertilized by Swede pollen, the Turnip being the seed-bearer, the seeds produced are rather paler in coat colour than those of the normal Turnip and always smaller and shrivelled. Moreover, it is difficult to germinate and rear seedlings from them in open ground, though there is little difficulty in doing this with the seeds of the reverse cross.

These points have been tested many times during two seasons, always with the same results.

At first the seeds of the crosses were sown in carefully prepared beds in the open ground; and from the fact that no plants were obtained from the seeds of the Swede ♂ on Turnip ♀ cross, we were inclined to conclude that the embryos in the seeds were abortive and incapable of growth.

However, in 1906 seeds from reciprocal crossings were again obtained, which showed the same striking differences in size, colour, and shape as were previously seen in the seeds, but instead of sowing them at once in the open ground they were germinated on blotting-paper and the seedlings planted out. Those of the Swede ♂ on Turnip ♀ were weak, but after careful management ultimately grew into plants as large as those from the Turnip ♂ on Swede ♀ cross. Moreover, the characters of the full-grown plants proved to be the same whichever way the cross was made.

The general facies of the plants was intermediate between the two parents. The leaves were glaucous like Swede leaves, but more hispid and more like those of the Turnip in shape. The "bulb" resembled the Swede in form and neck perhaps more than the Turnip, but the flesh was white like the latter. The flowers were almost as large as those of the Swede, but canary-yellow in colour, like those of the White-fleshed Turnip or White-fleshed Swede. They were abundant and apparently normal, but produced no seed although many were pollinated by hand. It was discovered later that the pollen was abnormal in form and structure, many of the pollen mother-cells having undergone peculiar changes which we hope to investigate further in the coming season.

The very marked sterility and the intermediate character of the plants obtained when the Swede (*Brassica campestris*, L., var. *Napo-brassica Rutabaga*, DC.) and White-fleshed Turnip (*Brassica Rapa*, L.) are crossed, seem to point strongly to the conclusion that they are true hybrids and that the parents are specifically distinct.

Apart from the fact that the plants are sterile, they are so different in character from the so-called "hybrid" yellow-fleshed Turnip, that it does not appear likely that the latter has originated by crossing the Swede and Turnip.

In addition to the Turnip × Swede cross just described, many others were made, including the following, which should probably be placed in this group :—

Colza Rape	on	Yellow-fleshed Tankard Swede.
Colza Rape	on	White-fleshed Round Swede.
Colza Rape	on	Yellow-fleshed Turnip.
White-fleshed Turnip	on	Colza Rape.

White-fleshed Turnip	on	White-fleshed Round Swede.
White-fleshed Turnip	on	Asparagus Kale.
White-fleshed Turnip	on	White-fleshed Swede.
White-fleshed Turnip	on	Yellow-fleshed Turnip.
White-fleshed Turnip	on	Yellow-fleshed Swede.
Yellow-fleshed Turnip	on	Colza Rape.
Yellow-fleshed Turnip	on	Ragged Jack Kale.
Yellow-fleshed Turnip	on	Yellow-fleshed Swede.
Yellow-fleshed Turnip	on	White-fleshed Swede.
Yellow-fleshed Turnip	on	White-fleshed Turnip.
Asparagus Kale	on	Yellow-fleshed Tankard Swede.
Ragged Jack Kale	on	Yellow-fleshed Tankard Swede.
Yellow-fleshed Round Swede	on	Ragged Jack Kale.

From all these crosses hybrid plants were obtained, many of which proved sterile, while others unfortunately died off in the winter before the question of their fertility or sterility could be ascertained.

The most interesting of these are shown in figs. 28 to 57 (Pls. 4 to 6).

Group III.—In this series of crosses abundant seed was produced, and plants of the F 1 and F 2 generation were easily raised.

The seeds from the F 1 generation were sown and about 200 plants from them were grown for observation. In the second filial generation (F 2) segregation occurred in all cases.

In order to obtain an impartial estimate of the numbers and characters of the plants, neither Professor Percival nor myself had anything to do with the classification of the segregated plants, this being left to the judgment of one of our assistants who had no inclination to look for Mendelian numbers. Many of the results, as will be seen below, are confirmatory of Mendel's laws. Where the figures appear to disagree with the well-known ratios among segregated plants of the F 2 generation, it is possible that the discrepancy may be due to the great difficulty in deciding into which group individual plants should be placed.

♂		♀
Ragged Jack Kale	on	White Swede.

Ragged Jack Kale (Pl. 7, fig. 58) is a form of *Brassica* which in general habit and flower resembles a Colza Rape but the leaves are lacinate. The Swede used for the female parent was a white-fleshed variety with purple top (fig. 59).

The plants of F 1 had strong Swede-like leaves; they were, however, slightly more incised at the margins than the normal Swede parent, indicating the influence of the Ragged Jack parent. The rootstock was thick with little tendency to "bulbing" (fig. 60).

The plants of the F 2 generation, of which 198 were grown, were of several forms. There were bulbing and non-bulbing plants, some having leaves like the Swede, others the lacinate form of the Ragged Jack Kale.

The following were the classes into which the plants of this generation were divided, together with numbers belonging to each class.

As regards foliage there were found—

142	with Swede foliage.
38	„ Ragged Jack foliage.
18	„ Intermediate foliage.

From the Mendelian ratio of 3 to 1, where Swede is dominant, we should expect from 196 plants—

147	with Swede foliage.
49	„ Ragged Jack foliage.

As regards the bulbing character there were—

	Found (198 plants).	Expected (from 196 plants).
Bulbed	160	147
Bulbless	38	49

Probably some of the 160 plants with bulbs should have been placed in the bulbless group, since it is difficult to distinguish slight bulb from a merely thickened stem due to increased vigour.

Classifying the plants obtained into groups with two pairs of characters in each, and an intermediate group, there were :—

	Found (198 plants).	Expected, according to the Mendelian ratio of 9.3×3.1 . from 199 plants.
Fig. 61. Bulbed with Swede foliage	117	112
„ 62. „ „ Ragged Jack foliage	30	} 43 37
„ 63. „ „ Intermediate foliage	13	
„ 64. Bulbless „ Swede foliage	25	37
„ 65. „ „ Ragged Jack foliage	8	} 13 13
„ 66. „ „ Intermediate foliage	5	

The intermediate plants showed evidence of Ragged Jack lacination, and should no doubt be placed with the Ragged Jack plants as indicated.

♂ ♀
White Swede on Ragged Jack Kale.

This was the reciprocal of the preceding cross (see figs. 58 & 59).

The plants of F 1 were bulbless and very similar to those of F 1 in the previous cross, but weaker in growth and slightly divided; the foliage was like that of the Swede with slight indication of Ragged Jack parent (see Pl. 8, fig. 67).

The plants of F 2 are shown at figs. 68 to 73 and tabulated below.

As regards foliage there were—

Found (194 plants).	Expected, 3 : 1 (from 192 plants).
156 with Swede foliage	144
33 „ Ragged Jack foliage	} 48
5 „ Intermediate foliage	

As regards bulbing character there were—

	Found (194 plants).	Expected (from 192 plants).
Bulbed	136	144
Bulbless	58	48

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Fig. 68. Bulbed with Swede foliage

♂ ♀
Kohl Rabi on Thousand-headed Kale.

The plants of F 1 were somewhat intermediate in character between the parents (fig. 76).

As regards the bulbing character there were :—

Pl. 9, fig. 77. 60 of the bulbed plants very closely resembled the Kohl Rabi grandparent in bulb, but had strong Thousand-headed Kale foliage.

„ 79. 53 had elongated thickened stems shorter than the typical Thousand-headed Kale ; the foliage was like that of the latter plant.

♂ ♀
Thousand-headed Kale on Kohl Rabi.

The plants of F 1 were intermediate in character between the parents as before described, having Thousand-headed Kale foliage and slight bulbing tendency (fig. 80).

As regards the bulbing character there were—

	Found (201 plants).	Expected (from 200 plants).
Bulbed	135	150
Bulbless	66	50

The bulbed plants included 44 well-developed Kohl Rabi against 60 in the reverse cross, and 66 slightly bulbed against 94 in the reverse cross. But amongst the bulbless plants none were seen resembling the Thousand-headed Kale as in the reverse cross, though there were 38 with broad leaves like a Cabbage, quite unlike either parent.

Fig. 81. 44 were almost pure Kohl Rabi with coarse foliage.

„ 82. 91 like the 94 in the reverse, *i.e.* Thousand-headed Kale foliage and slight bulb.

„ 83. 28 were bulbless with Kohl Rabi foliage.

„ 84. 38 had broad Cabbage-like leaves with a bulbless elongated stem.

From the $9 : 3 \times 3 : 1$ Mendelian ratio, we should expect :—

				From 208 plants.
Bulbed, Thousand-headed Kale foliage	...	...	...	117
„ Kohl Rabi foliage	...	...	...	39
Bulbless, Thousand-headed Kale foliage	...	...	...	39
„ Kohl Rabi foliage	...	...	...	13

$\begin{matrix} \text{♂} & & \text{♀} \\ \text{Kohl Rabi} & \text{on} & \text{Drumhead Cabbage} \\ & & \text{(Pl. 10, figs. 85 \& 86).} \end{matrix}$

The plants of F 1 in this cross had slight indication of the bulbing character with foliage resembling that of the Cabbage. There was, however, no sign of the “hearting” tendency of the Cabbage (fig. 87).

215 plants were raised of the F 2 generation (see figs. 88, 89 & 90). Of these :—

Fig. 88. 45 had distinct Kohl Rabi bulbs and foliage.

„ 89. 154 had rather enlarged stems, as if influenced by Kohl Rabi, the foliage being variable and undeterminate.

„ 90. Only 16 plants had leaves closely resembling those of the Cabbage.

As regards typical Kohl Rabi plants there were—

	Found (215 plants).	Expected (from 216 plants).
Kohl Rabi	45	54
Not Kohl Rabi	170	162

In the reciprocal cross :—

$\begin{matrix} \text{♂} & & \text{♀} \\ \text{Drumhead Cabbage} & \text{on} & \text{Kohl Rabi (see figs. 85 \& 86),} \end{matrix}$

the plants of F 1 were similar to those of F 1 in the reverse cross, having Cabbage-like leaves and a slight bulb (fig. 91).

195 plants were grown of the F 2 generation (see figs. 92, 93, 94 & 95, Pl. 11). Of these—

Fig. 92. 46 were like Kohl Rabi (2 of these purple-leaved).

„ 93. 8 had leaves like Cabbage (6 of these purple).

„ 94. 140 had enlarged stems with foliage of variable character.

„ 95. 1 resembled a Kale with a “curled” or “fringed” leaf.

2. Forms of *Brassica oleracea*, L. (all of which have smooth glaucous leaves in all stages of their growth), did not cross with those of Turnip (*Brassica Rapa*, L.), Swede Turnips (*Brassica campestris*, L., var. *Napo-brassica*, DC.), or various kinds of oil-yielding Rapes, all of which have hispid leaves when young.
3. No form of Rape was met with which had smooth leaves.
4. Rapes, Turnips, and Swedes cross readily with each other.

The plants obtained by crossing the (hispid green-leaved) Turnip with the (hispid glaucous-leaved) Swede proved sterile.

The Turnip and Swede-Turnip are no doubt specifically distinct.

Ragged Jack Kale and Asparagus Kale produce fertile crosses with Swede.

All have hispid glaucous leaves when young.

5. The so-called "Hybrid" yellow-fleshed Turnip cannot have been obtained by crossing the Swede with the Turnip.
6. The relationship between the white- and the yellow-fleshed forms, both of Turnips and Swedes, is still unsettled.
7. Several of the crosses and their progeny exhibit simple Mendelian phenomena, but there are many points connected with the occurrences of new features, such as novel colour and altered form of leaf, in the segregates of F 2, which are not clearly understood.

The peculiar and apparently distinct character of "fleshiness" possessed by the seedsmen's specially selected forms of "roots" is very much reduced in the F 1 plants, and its occurrence in these may be readily confused with increased vigour of stem. It returns, however, in the F 2 generation in increased intensity, but none of these plants seem to possess it in the same degree as the original parents of the cross.

In the crosses where the green Drumhead Cabbage was one of the parents, a few plants having purple foliage were met with in the F 2 generation.

In preparing this paper for publication in the Society's Journal, I have had the valued help of Professor Percival.

EXPLANATION OF THE PLATES.

PLATE 1.

Fig. 1. Green Kale.

2. Variegated Kale.

3. Thousand-headed Kale.

4. Savoy.

5. Brussels Sprouts.

Fig. 6. Drumhead Field Cabbage.

7. Garden Cabbage.

8. Red Cabbage.

9. Couve Tronchuda.

PLATE 2.

Fig. 10. A Brussels Sprouts plant with Cabbage head.

11. A new hardy curled form of Thousand-headed Kale.

12. A plant of the habit of Thousand-headed Kale, but having very white and tender leaf-stalks of the nature of Couve Tronchuda.

13. A heading or hearting form of Couve Tronchuda.

14. True Thousand-headed Kale (for comparison).

15. True Couve Tronchuda (for comparison).

PLATE 3.

Types of roots and plants used in the experiments (see page 2) :—

Fig. 16. Colza Rape.	Fig. 20. Thousand-headed Kale.
17. Ragged Jack Kale.	21. Drumhead Cabbage.
18. Asparagus Kale.	Figs. 22-24. Swede Turnips.
19. Kohl Rabi.	25-27. Turnips.

PLATE 4.

Fig. 28. Asparagus Kale
on	Fig. 31. White Turnip
on
29. Yellow-fleshed Swede.	32. Asparagus Kale.
30. Type of plant produced in F 1.	33. Type of plant produced in F 1.

- Fig. 34. Ragged Jack Kale
on
35. Yellow-fleshed Swede.
36. Type of plant produced in F 1.

PLATE 5.

Fig. 37. Yellow-fleshed Swede
on	Fig. 40. Colza Rape
on
38. Ragged Jack Kale.	41. Yellow-fleshed Swede.
39. Type of plant produced in F 1.	42. Type of plant produced in F 1.

- Fig. 43. Colza Rape
on
44. White-fleshed Swede.
45. Type of plant produced in F 1.

PLATE 6.

Fig. 46. White-fleshed Turnip
on	Fig. 52. Yellow-fleshed Turnip
on
47. Colza Rape.	53. Ragged Jack Kale.
48. Type of plant produced in F 1.	54. Type of plant produced in F 1.
49. Yellow-fleshed Turnip
on	55. White-fleshed Turnip
on
50. Colza Rape.	56. White Swede.
51. Type of plant produced in F 1.	57. Type of plant produced in F 1.

PLATE 7.

- Fig. 58. Ragged Jack Kale. ♂.
59. White-fleshed Swede. ♀.
60. Plant of F 1 generation of Ragged Jack Kale (♂) on White Swede (♀).
- Figs. 61-65. Plants of F 2 generation.

PLATE 8.

- Fig. 67. Plant of F 1 generation of White Swede (♂) on Ragged Jack Kale (♀).
Figs. 68-73. Plants of F 2 generation.
Fig. 74. Kohl Rabi (♂).
75. Thousand-headed Kale (♀).
76. Plant of F 1 generation of Kohl Rabi (♂) on Thousand-headed Kale (♀).

PLATE 9.

- Figs. 77-79. Plants of F 2 generation of Kohl Rabi (♂) on Thousand-headed Kale (♀).
Fig. 80. Plant of F 1 generation of Thousand-headed Kale (♂) on Kohl Rabi (♀).
Figs. 81-84. Plants of F 2 generation.

PLATE 10.

- Fig. 85. Kohl Rabi (♂).
86. Drumhead Cabbage (♀).
87. Plant of F 1 generation of Kohl Rabi (♂) on Drumhead Cabbage (♀).
Figs. 88-90. Plants of F 2 generation.
Fig. 91. Plant of F 1 generation of Drumhead Cabbage (♂) on Kohl Rabi (♀).

PLATE 11.

- Figs. 92-95. Plants of F 2 generation of Drumhead Cabbage (♂) on Kohl Rabi (♀).
Fig. 96. Thousand-headed Kale (♂).
97. Drumhead Cabbage (♀).
Figs. 98-100. Plants of F 2 generation of Thousand-headed Kale (♂) on Drumhead Cabbage (♀).

PLATE 12.

- Fig. 101. Purple-top Swede (♂).
102. Asparagus Kale (♀).
103. Plant of F 1 generation of Purple-top Swede (♂) on Asparagus Kale (♀).
Figs. 104-107. Plants of F 2 generation.
-

PLATE 1.

BRASSICA CROSSES.

PLATE 2.

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BRASSICA CROSSES.

PLATE 3.

BRASSICA CROSSES.

PLATE 4.

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BRASSICA CROSSES.

PLATE 5.

BRASSICA CROSSES.

PLATE 6.

BRASSICA CROSSES.

PLATE 7.

BRASSICA CROSSES.

PLATE 8.

BRASSICA CROSSES.

PLATE 9.

BRASSICA CROSSES.

BRASSICA CROSSES.

PLATE 11.

BRASSICA CROSSES.

PLATE 12.

BRASSICA CROSSES.

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