

Major Thesis

on

HYBRIDIZATION EXPERIMENTS WITH THE RADISH

submitted to

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by

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HYBRIDIZATION EXPERIMENTS WITH THE RADISH.

Origin of the Radish.

The origin of the common garden radish, *Raphanus sativus*, is not entirely clear. It is generally supposed that it came from some wild plant, native to the temperate part of Asia, which wild plant is now extinct. However, no one is sure of this point.

Some people think that the common garden radish is just an improved form of the wild charlock, *Raphanus Raphanistrum*. M. Carriere carried on experiments with this wild plant for five years and in that time he produced all the important radish shapes. By continual selection, he also produced the following colors of tuber: white, red, brown, black, and deep violet. This experiment of Carriere's shows the possibilities of selection on some of our wild plants.

History of the Radish.

The history of the radish dates back to 450 B. C. when Herodotus, in describing the building of the great pyramid of Egypt, mentioned an inscription which stated the amount expended in radishes for the workmen. Pliny gives a good description of several varieties of radish or rather "Radicicola" or "Little Root" as he called it. He gives full cultural directions and also a way of reducing the natural pungency of this root by watering with brine. Judging from his description, it seems that the radish was fairly well developed at this early date and was equal to the present radishes, at least in size.

Jumping to the 16th century, we find a number of illustrations and descriptions of the radish which show that several different shapes of tubers were coming into cultivation. These writers describe the radish

under various names. Descriptions of this vegetable are numerous throughout the 17th, 18th, and 19th centuries and all the characters of the plant seem to be very variable. The prominent constrictions of the siliques, as noted by the earlier writers, seem to have gradually become less and less prominent down to the present time.

The Variability of the Radish.

Taken as a whole the varieties of radish are very variable in regard to the majority of their characteristics. In regard to color of flowers, no variety grown was absolutely true to any type. The color ranged from dark lilac to pure white. The color of the veins of the petals varied in the same way. Some varieties had a predominating color or shade of flower but there were always a large number with a different shade.

This same variability existed in regard to color of stalk. For instance, most of the plants of a certain variety would have a green stalk but some would have reddish stalks.

In regard to shape or rather the amount of pinnation, some varieties are very variable as shown by the accompanying photograph of the fourth leaf of three plants of the variety "Long Scarlet Short Top". Some other varieties are fairly true to type.

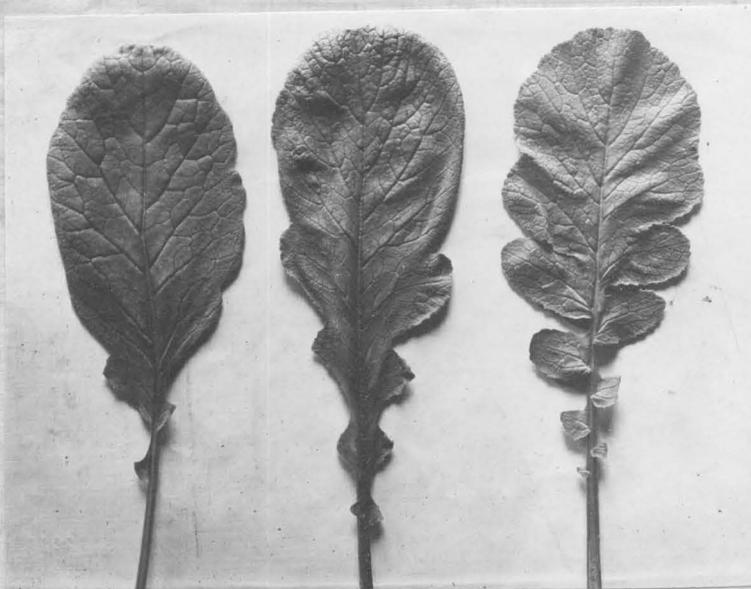


Fig. 1.

raceme of the male parent was covered with a thin paper bag before blossoming and pollen was taken from this Methods. All racemes which were not needed for seed or for pollen were cut off so as to further reduce the danger

of a mistake. There were several diseases which caused a lot of trouble in this work. In several cases every plant of certain crosses was killed by the rot. Some plants were lost from dampness. After about the first four weeks of growth, the leaves and stalks were badly attacked by a species of *Alternaria*. This disease caused more loss in the open than in the greenhouse. *Cytophus candidus* was destructive to the leaves and floral shoots. A soft stinking bacterial rot of the tuber was very bad, in some cases killing every plant for a distance of three feet.

In the fall of 1909, radish seed were planted in a side bed of the greenhouse, one row to each variety. The radish germinates and grows quickly. Most of the varieties were in full bloom by February.

The flowers are borne in a raceme on stalks which grow from nearly every leaf axil of the plant. However, the first and apparently the strongest flowers are borne on the top central stalk and whenever possible, this central stalk was used in crossing.

When about fifteen or twenty buds of a raceme had reached the proper state of development, they were emasculated and all the remaining buds cut off. The emasculations were made from two to five days before the buds opened. The radish is a very simple flower to work with. Using a pair of forceps, the sepals and petals were gently opened out and the six stamens removed, counting them as they were taken out. A thin paper bag was immediately tied over the raceme.

The flowers were pollinated twice, on about the second and fourth days after emasculation. The bags were removed after almost two weeks, by which time the pods were partially developed. Usually one

raceme of the male parent was covered with a thin paper bag before blooming and pollen was taken from this source. All racemes which were not needed for seed or for pollen were cut off so as to further reduce the danger of a miscross. In all of the radish crosses, nearly every flower pollinated, set. The chief trouble was in getting the two parents to bloom at the same time. During the first year, no crosses were secured with Black Spanish because this variety did not bloom before June, when school closed.

The F_1 plants were cared for in the same way as the parents. Several rows of each cross were planted. When the tubers had reached a fair size, they were pulled up and all of the leaves removed except the very youngest. They were thoroughly washed, then graded, and notes taken. Care was taken in regard to keeping labels straight and so forth, only one variety being pulled at a time. The tubers selected for seed were then replanted in a new location.

When the F_1 plants came into bloom, the racemes were bagged and an attempt was made to secure seed by shaking each daily so as to scatter the pollen about in the bag. No pistils set, however. Careful hand pollination of stigmas with pollen from the same plant gave us no results, so it was concluded that the F_1 plants were not self fertile. It was necessary to transfer pollen from one plant of a cross to another of the same cross. The pollination work on the F_1 generation took a lot of time to secure enough seed. Some of the crosses were lost on account of diseases and failure of different plants to bloom near enough together.

No. 6. Favorite Forcing. In shape, this radish is a cross between an olive and a globe. Color is deep scarlet with a scarlet tip though a few were found with white tip.

Description of Parents.

No. 1. Long Icicle.-- This is a long fusiform radish. Color of root is pure transparent white. Leaves are short and rather small. Growth in general is poor and bloomstalk weak.

No. 2. Woods Early Forcing.-- This variety is very similar to No. 5, differing in that the tubers are more sunken in the soil and the top is more vigorous. This is a long scarlet radish which has in some cases a very small white tip.

No. 3. Scarlet White Tipped Turnip. Tuber is roundish to turnip shaped, slightly flattened on the under side. Color is deep scarlet shading down to a pure white tip. A few did not have this white tip. Leaves are slightly pinnatifid.

No. 4. Celestial. This is a large round to oblong radish with a stump root. Color is pure white but still not exactly like the transparent white of No. 1. Leaves are light green and much pinnatifid or divided. All of the plants were true to type in regard to leaves. This variety is very slow in regard to tuber formation, all the growth at first seeming to go into the leaves. The young plant often bent over on the ground, not standing upright like most of the other varieties.

No. 5. Long Scarlet Short Top. This variety has a long bright scarlet tuber without a white tip. One very characteristic thing is that about half of the tuber is formed above the surface of the ground. Most radishes have only the neck above ground. The leaves are short and small.

No. 6. Favorite Forcing. In shape, this radish is a cross between an olive and a globe. Color is deep scarlet with a scarlet tip though a few were found with white tip.

No. 7. Black Spanish. This is a long black radish with a black tip. Skin seems to be rather thick. It is a very slow grower. Leaves are much divided or pinnatifid, even more so than those of Celestial.

No. 8. White Turnip. This is a large white turnip shaped radish.

No. 9. Golden Globe. This is a roundish shaped radish with a rather thick yellowish brown skin. The leaves are, on the whole, only slightly pinnatifid, much less so than any of the other varieties.

Crosses between No. 5 and No. 4 gave complete dominance of the pinnatifid leaf in the F_1 generation. The F_2 generation also showed the dominance of the pinnatifid leaf but they varied somewhat. The pinnatifid condition was not as strong in the F_2 plants as in the parent.

Crosses between No. 4 and No. 9 in the F_1 generation gave absolute dominance of the pinnatifid leaf. A cross between No. 7, a pinnatifid leaved variety, and No. 9 also gave absolute dominance of the pinnatifid condition in the F_1 generation. The F_2 plants of these two crosses will be grown this spring.

Inheritance of Form of Leaf.

Most of the varieties of radishes varied as regards form of leaf. This is shown by Fig. 1 in the first part of this thesis. However, there are certain varieties which are fairly uniform in regard to leaf form. No. 4 Celestial, has a much pinnatifid leaf; No. 3 Scarlet White Tipped Turnip has a slightly pinnatifid leaf; and No. 9, Golden Globe has an unpinnatifid leaf.

Crosses between No. 3 and No. 4 gave complete dominance of the pinnatifid leaf in the F_1 generation. The F_2 generation also showed the dominance of the pinnatifid leaf but they varied somewhat. The pinnatifid condition was not as strong in the F_2 plants as in the parent.

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About the same can be said in regard to the turnip shaped class.

1×3 is another shape cross that differs somewhat from the results of the preceding crosses. No. 5 is a long tuber, No. 8 is turnip shaped. The F_1 generation was somewhat of a mean between the two with the long parent the stronger. The F_2 generation were somewhat similar to the F_1 , though breaking up a little, still the long parent was decidedly the stronger.

Inheritance of Shape of Tuber.

Five crosses, representing the most difference in shape of tuber of the parents, may be considered here. 1×3 , 6×1 , and 1×4 may be taken up together. No. 1 is a long fusiform radish. Nos. 3, 4, and 6 are roundish to turnip shape. The F_1 plants from these crosses were all somewhat turnip shaped but a little more elongated turnip shape than the parent. They varied somewhat but showed dominance of turnip shape over fusiform in the F_1 . The F_2 generation was mostly a mean between the fusiform and turnip. There were tubers which tended towards the fusiform or turnip class but none had either shape to the same degree as the parent.

1×8 gave a little more definite breaking up in the F_2 generation. No. 1 is fusiform in shape. No. 8 is turnip in shape. The F_1 tuber was fairly uniform in regard to its shape, which was elongated turnip. The F_2 tubers varied greatly in regard to shape. Three classes were made: fusiform, intermediate, and turnip. The results were 20 fusiform, 61 intermediate, and 23 turnip shaped tubers. In many cases, it was hard to tell where to place the tubers, whether in the fusiform or intermediate class, and again whether in turnip or intermediate. The best fusiform tuber in that class did not come up to the fusiform type of the parent. About the same can be said in regard to the turnip shaped class.

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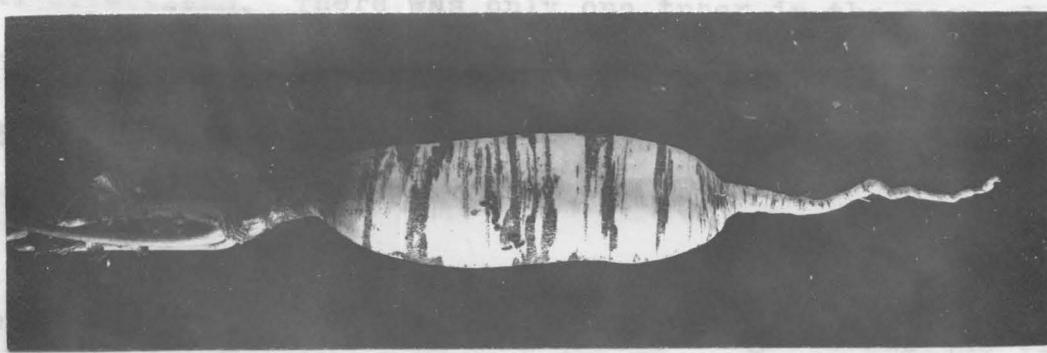
Inheritance of Color of Tuber. and scarlet radishes

were rather hard to classify. There was no trouble

No. 9 Golden Globe × No. 4 Celestial.- No. 9 is of a yellowish brown color while No. 4 is white. The F₁ generation is a blend, considering the 18 plants as a whole. The upper part of the tuber is mostly a dark brown color, while the lower 4/5 is white. The tubers varied somewhat in regard to the amount of brown color. On the majority, the brown appeared mostly on that part of the tuber exposed to the light, while on others it appeared well beneath the soil. This brownish color seems to be a mere skin or coating, laid on over the white skin of the tuber. If tuber is scraped gently or rubbed hard with the hand, this coating comes off leaving the white skin beneath. The F₂ generation is being grown now.

No. 4 Celestial × No. 7 Black Spanish.- No. 4 is a white and No. 7 a solid black radish. The F₁ generation of twenty-one plants showed a pretty case of mosaic inheritance. In every case, the top half inch of tuber was black but not as dark a shade of black as the parent. The rest of the tuber on an average was mostly white with about one-fourth of the surface black in streaks as the picture shows.

Fig. 2



(36) were plants but not 10. 5 pure white tip as with some of the crosses. The F₂ generation gave 40 pure white 30 rose 11 5 magenta. As with most of the crosses, the

The results of the crosses between white and scarlet radishes were rather confusing and very hard to classify. There was no trouble with the F₁ generation. The F₂ tubers were graded into three classes; white, rose and magenta. A color chart was used in this grading. Even with this chart, there were many tubers which were just on the dividing line of the classes and could have been placed in either. The top of the tuber was made the point of classification. For instance, if the top of the tuber was light rose and the rest of the tuber white, it was placed in the rose class even though three-fourths of it was white. It was the same way with the magenta. No tubers were found with both magenta and rose but there were a good many just on the boundary line between these colors. The white class includes only pure whites. This was a rather rough method of classification, but the tubers were so variable, that no better method was found.

The scarlet parents were Nos. 3, 5, and 6. No. 3 had a white tip; the other two were solid scarlet. The white parents were Nos. 1, 4, and 8, all pure white.

No. 6 Favorite Forcing × No. 1 Icicle.- The F₁ plants (13) were a rosy magenta at the top of tuber shading down to a whitish tip. The F₂ generation was as follows: 72 pure white, 40 rose, 1 drab, and 118 magenta. The magenta and rose class were not at all uniform, shading off in all directions. There was only one tuber in the rose class that approached the deep scarlet of the parent. This is a peculiar fact, that in the F₂ generation, none of the plants have the same scarlet color as one of the parents.

No. 5 Long Scarlet Short Top × No. 1 Icicle.- The F₁ plants (36) were reddish magenta at the top, diminishing towards the tip but not to a pure white tip as with some of the crosses. The F₂ generation gave 49 pure white, 38 rose and 94 magenta. As with most of the crosses, the

rose and magenta classes were very variable. None of the F₂ plants came up to the deep scarlet of the parent.

No. 3 Scarlet White Tipped Turnip × No. 4 Celestial.- The F₁ plants (46) were somewhat variable in regard to color, varying from rose to magenta. The mean falls somewhere between these two colors. The lower part of the tuber was usually white. The rosy magenta color often appeared in bands or raised places on the lower part of the tuber.

The F₂ generation gave 49 pure white, 60 rose and 85 magenta. There were a number of tubers in the rose class that might have been put into a scarlet class but still none of them came up to the degree of scarlet of the parent. There were several very dark magenta tubers, which were almost black.

No. 4 Celestial × No. 3 Scarlet White Tipped Turnip.- This is the only reciprocal cross that was carried to the F₂ generation. Several others were made but were killed out by the bacterial root rot in the F₁ generation. The F₁ plants (13) were similar to the preceding cross. The F₂ generation gave 19 pure white, 26 rose, and 30 magenta.

No. 5 Long Scarlet Short Top × No. 8 White Turnip.- The F₁ plants were clearly magenta. The F₂ plants were 7 white, 11 rose, and 23 magenta. Classes graded into each other somewhat.

No. 1 Icicle × No. 3 Scarlet White Tipped Turnip.- The F₁ plants (11) were very uniform being dark magenta at top shading down to a light tip. The F₂ generation gave 4 pure white, 19 rose, and 51 magenta. The magenta and rose classes were of a rather light shade. The small number of whites in the F₂ generation was rather peculiar, especially since the scarlet parent was partly white.

No. 8 White Turnip × No. 3 Scarlet White Tipped Turnip.- The F₁ plants (17) of this cross were also very uniform, being a dark magenta shading

down to a light tip. The F₂ generation was easy to classify, there being no plants that were on the boundary line of the classes. The numbers were 34 white, 26 rose, and 83 magenta.

Discussion of the Scarlet and White Crosses.

The results of the crosses between scarlet and white radishes are somewhat difficult of explanation. A summary of all the F₂ plants follows:

Cross	White	Rose	Magenta
♀ ♂ 6 × 1 =	72	40	118
5 × 1 =	49	38	94
3 × 4 =	49	60	85
4 × 3 =	19	26	30
5 × 8 =	7	11	23
1 × 3 =	4	19	51
8 × 3 =	34	26	83
	<hr/> 234	<hr/> 220	<hr/> 484

This summary is very close to the mendelion ratio of 1-2-1 for the F₂ generation. Taking the results in this light, we would consider the magenta as the hybrid color which seems to be perfectly right as most of the F₁ generation were of this color. However, this magenta class contains tubers that had only a very slight amount of light shade of magenta at the top, while over half of the tuber was pure white. Other tubers were a very dark magenta all over.

The rose class also contains many tubers with only a very light shade of rose at the top while most of the tuber is white. Somehow it does not seem that tubers like this should be placed in the rose class and

yet if strict consideration of the presence or absence of rose is the basis of classification, which was the basis, then they belong here.

Another point to be noted is that although the rose class is considered as reverting to the scarlet parent, yet this rose class contains only a few tubers that have the deep scarlet color of the parent. It is rather hard to understand why in the F_2 generation of the crosses, so few tubers showed the scarlet color.

It should also be noted that the 1-2-1 proportion will not figure out at all with a good many of the crosses. Thus in the cross of White Icicle X Scarlet Turnip, only 4 whites were secured in the F_2 generation out of 74 plants. Tubers from each of these classes are being grown in the greenhouse at the present time and the F_3 generation will perhaps make things a little plainer.

I believe that the commercial varieties of radishes have a rather complex make up in regard to this color. That is that there are several different factors or determiners for scarlet and that when crossed, these plants break up in ways that are somewhat hard to explain.

Perhaps it should be mentioned here in connection with my work in plant breeding that a cross was effected between the radish and the cabbage. The work with this cross has been reported on elsewhere.