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Inheritance of Seven Characters in *Raphanus sativus* L.[1]

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Abstract. **The inheritance of 7 characters in *Raphanus sativus* L. was studied. Resistant reaction to *Albugo candida* race 1, Ac_1, pink pigmentation in plants, *Pi*, and purple colored pods in *R. sativus* var. *caudatus*, *Pu*, are controlled by single dominant genes, Ac_1 and *Pi* are linked and 3.28 map units apart. Male sterility, ms_1, yellow-green leaves, *yg*, and cream pollen, *cp*, are all controlled by separate, single recessive genes. Digenic recessives, gf_1gf_2, control green flecking on leaves. No linkage could be detected between Ac_1 and ms_1 or between ms_1 and *yg*.**

Information on the linkage of marker genes with genes for resistance to numerous diseases in radish is useful in plant breeding (2, 6, 9). Inheritance and linkage studies were conducted among some of the genes controlling 7 distinctive traits in our radish collections.

In order to establish homozygosity for each character under investigation, parental lines were self-pollinated twice successively. Self-incompatibility was overcome by bud pollination (3). Controlled crosses were made to produce F_1 and F_2 progenies. Unless indicated, radishes were grown and flowered in 10 cm pots in an air-conditioned greenhouse at 20-24°C.

Inoculations with *Albugo candida* race 1 (Pers.) Kuntze were made by thoroughly wetting the cotyledons of 7-day-old radish seedlings with a zoospore suspension of 5×10^4 zoospores/ml, sprayed from a deVilbiss atomizer. Inoculated seedlings were held for 24 hr in a saturated atmosphere at 15°C, then transferred to a greenhouse bench at 20°C and provided with continuous illumination from 10,000 lux of a 1:1 mixture of Sylvania cool white and Grolux fluorescent bulbs. White rust developed on the cotyledons of susceptible seedlings and symptoms were read 7 days after inoculation (9). Resistance was expressed as the absence of white rust pustules.

As previously reported by Williams and Pound (9), resistance in 'China Rose Winter' to the white rust disease was controlled by a single dominant gene (Table 1). We propose, however, to change the gene designation *R* into the more descriptive symbol Ac_1, derived from the initials and race no. of *Albugo candida* race 1.

A few male sterile plants were found among the selfed progenies of an 'Early Scarlet Globe' parent. No pollen was produced on the anthers of male sterile plants, and the buds were approx half the size of those on the male fertile siblings. These male sterile plants were completely female fertile. Male sterility was found to be controlled by a single recessive gene (Table 1). Since a gene for male sterility, *ms*, has been previously reported in a Japanese radish (8), we have designated this new gene ms_1, pending an allelic test.

In studying the inheritance of pink pigmentation in the radish plant, a line of 'China Rose Winter' was selected which was true breeding for uniform pink roots, stems and flowers. From crosses made to the nonpigmented 'White Spike' plants, we found that pink pigmentation was controlled by a single dominant gene, designated *Pi*, for pink (Table 1).

A plant in Wisconsin breeding line 1735, was found to have cream-colored pollen in contrast to the bright yellow pollen of normal plants. All selfed progenies had cream pollen. This character was found to be controlled by a single recessive gene, designated *cp* (Table 1).

The long pods of *R. sativus* var. *caudatus* L. from PI 179982 are either green or purple, however the intensity of purple pigmentation is variable. Data obtained from F_1 and F_2 progenies grown in the field indicate that purple pigmentation in the pods is controlled by a single dominant gene, designated *Pu* (Table 1). Though the intensity of pigmentation in pods of F_1 progenies approached that of the parent, it was variable in the pods of F_2 progenies, indicating possible modifying genes.

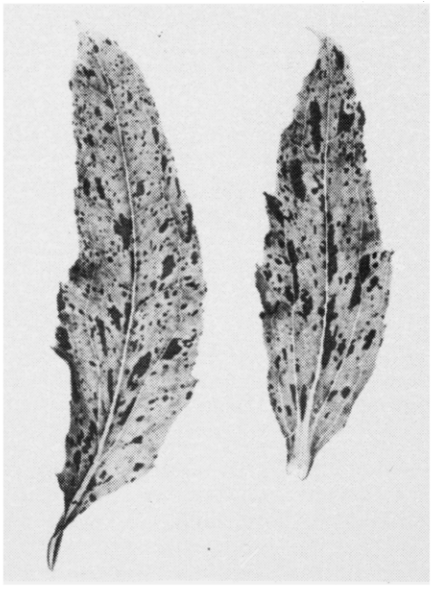

Fig. 1. Green fleck on radish leaves controlled by two recessive genes gf_1gf_2.

A seedling having yellow-green cotyledons gradually became normal green about 12 days after emergence, while the true leaves remained yellow-green for the life of the plant. Selfed progenies were identical to the parent. Mature yellow-green plants were stunted, though completely fertile. This yellow-green character was found to be controlled by a single recessive gene, designated *yg* (Table 1).

Another chlorophyll-deficient mutant was found in a population of 'Early Scarlet Globe'. This mutant had yellow-green cotyledons which gradually turned light green; however, the true leaves had a distinctive normal green fleck on the yellow-green background (Fig. 1). The selfed progenies from this mutant were identical to the

Table 1. Summary of data of F_1 and F_2 progenies classified for 7 characters of radish.

Parental genotype[z]	No. of plants: F_1 phenotype +	F_1 phenotype –	F_2 phenotype +	F_2 phenotype –	Expected F_2 ratio	X^2	P
$Ac_1Ac_1 \times ac_1ac_1$	36	0	105	40	3:1	0.59	0.50–0.25
$ms_1ms_1 \times Ms_1Ms_1$	50	0	296	101	3:1	0.05	0.90–0.75
Pi Pi × *pi pi*	71	0	218	68	3:1	0.23	0.75–0.50
Cp Cp × *cp cp*	18	0	66	23	3:1	0.03	0.90–0.75
Pu Pu × *pu pu*	19	0	102	39	3:1	0.53	0.50–0.25
Yg Yg × *yg yg*	42	0	213	71	3:1	0.00	1.0
$gf_1gf_1\ gf_2gf_2 \times Gf_1Gf_1\ Gf_2Gf_2$	15	0	52	5	15:1	0.62	0.50–0.25

[z] Ac_1 = controls resistance to white rust, ms_1 = male sterile, *Pi* = pink pigmentation, *cp* = cream pollen, *Pu* = purple pods, *yg* = yellow-green leaves, and gf_1gf_2 = green fleck of leaves. + –, Dominant (+), recessive (–) phenotype.

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parent. The plants were stunted, but fully fertile. The green fleck character was controlled by two recessive genes, designated gf_1gf_2 (Table 1). The F_1 progenies of a cross made between a yellow-green parent (*yg*) and a green fleck parent (gf_1gf_2) were vigorous and normal, indicating that different genes were involved.

Linkage between Ac_1 and *Pi* was detected with a recombination value of 3.28% (Table 2) using Mather's formula (3). No linkage was detected between Ac_1 and ms_1 nor between ms_1 and *yg*. The above linkage in 'China Rose Winter' plants may be of importance for radish breeders. By carefully controlling the initial crosses, it is possible to select in the field for root color as well as for resistance against white rust.

The observed close linkage might also be utilized as a means of re-examining the question as to the no. and expression of genes controlling root color in radish (1, 4, 7, 10). By selecting recombinants Ac_1Ac_1, *pi pi* which are resistant to *A. candida* race 1 and completely green, and crossing them to lines having various pigmentations, the relationship among the various factors governing pigmentation in radish plants, could be determined. The presence or absence of linkage between Ac_1 and gene(s) controlling production of pigments would help establish whether one or more loci are involved in radish color.

Table 2. Summary of F_2 segregation in 3 crosses of radish.

Parental genotype[z]	F_2 segregation: parental classes ++	parental classes −−	recombinant classes +−	recombinant classes −+	X^2 for linkage	P (9:3:3:1)	Map units
Ac_1Ac_1 *Pi Pi* × ac_1ac_1 *pi pi*	230	73	5	11	245.2	<0.005	3.28
ac_1ac_1 ms_1ms_1 × Ac_1Ac_1 *Pi Pi*	13	1	4	4	0.02	0.90–0.75	–
	+−	−+	++	−−			
Ms_1Ms_1 *yg yg* × ms_1ms_1 *Yg Yg*	6	6	20	4	0.06	0.90–0.75	–

[z] Ac_1 = resistance to white rust; *Pi* = pink pigmentation in plant; ms_1 = male sterile; *yg* = yellow-green leaves.
+ − Dominant (+), recessive (−) phenotypes in gene order of parents.

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Gibberellin-like Substances of 3 Species of *Lycopersicon*[1]

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Abstract. **Gibberellin-like substances (GAs) were demonstrated in the ethyl acetate-soluble basic, acidic and bound fractions of *Lycopersicon pimpinellifolium* (Jusl.), *L. peruvianum* (L.) Mill and *L. hirsutum* Humb. & Bonpl. The distribution of GAs activity differs in the fractions of the 3 species. The total amount of GAs of *L. pimpinellifolium* was 96-fold and 44-fold that of *L. peruvianum* and *L. hirsutum*, respectively. The vegetative growth of the species may be inversely related to the content of GAs.**

The presence of endogenous GAs in the seeds and shoots of *Lycopersicon esculentum* Mill. has been demonstrated (1, 2, 3, 4, 5, 6). This study was carried out to determine the presence of GAs of 3 other species of *Lycopersicon*.

Tomato seeds (*L. peruvianum, L. pim-pinellifolium* and *L. hirsutum*) for this study were obtained from Dr. Miquel Holle (National Agricultural University, La Molina, Lima, Peru). The seeds were sown in a medium of 1 vermiculite:1 fine white quartz sand (v/v), and germinated in a growth chamber maintained at 26°C (day) and 20° (night). Seedlings received a 12-hr photoperiod from mixed cool white fluorescent and incandescent lamps at 13 klx.

For extraction, 4-week old tomato shoot tissues of the 3 species were used. Twenty-six plants (2.5 g fresh wt) of *L. hirsutum,* 110 plants (7.0 g fresh wt) of *L. peruvianum,* and 150 plants (8.3 g fresh wt) of *L. pimpinellifolium* were available for extraction. The procedures for GAs extraction into ethyl acetate, paper chromatography and bioassay were the same as previously reported (1). The bioassay employed was based upon the gibberellin-induced disappearance of tomato hypocotyl anthocyanin with increasing gibberellin concn. Although the bioassay was shown to be sensitive to gibberellin A_1, A_3, $A_{4/7}$, A_5 and A_{13}, it was relatively insensitive to indole-3-acidic acid and 6-benzylamino purine. $GA_{4/7}$ was used as standard because the discoloration of the anthocyanin from the hypocotyl tissues showed the best linearity with increasing gibberellin concn.

The GAs of the basic, acidic and bound fractions of *L. pimpinellifolium* showed significant anthocyanin-decolorising activity at Rfs 0.7, 0.6–0.8 and 0.6–0.8, respectively. In *L. peruvianum,* GAs activity was detected at Rfs 0.1–0.2, 0.4, 0.6 and 0.9–1.0 of the basic fraction, Rfs 0.8–1.0 of the acidic fraction, and Rfs 0.1–0.2, 0.4 and 0.8 of the bound fraction. The GAs of the basic, acidic and bound fractions of *L. hirsutum* indicated significant activity at Rfs 0.1, 0.3, 0.5–0.6 and 0.9–1.0, Rf 1.0 and Rfs 0.4 and 0.8 respectively. The basic fraction of *L. peruvianum* and *L. hirsutum* showed significant GAs activity at Rfs 0.9–1.0, but similar activity at the same Rf regions was absent in *L. pimpinellifolium.* In contrast, GAs activity at Rfs 0.6–0.7 of the acidic and bound fractions of *L. pimpinellifolium* was absent in similar fractions of *L. peruvianum* and *L. hirsutum* (Fig. 1).

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