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.

Literature Cited

1. Harborne, J. B., and C. J. Paxman. 1964. Genetics of anthocyanins production in the radish. *Heredity* 19:505-507.
2. Humaydan, H. S., P. H. Williams, B. J. Jacobsen, and H. L. Bissonnette. 1976. Resistance in radish to *Aphanomyces raphani* and *Rhizoctonia solani*. *Plant Dis. Rptr.* 60:156-160.
3. Mather, K. 1938. The measurement of linkage in heredity. London, Methuen and Co. Ltd.
4. Okuno, S. 1943. The genetics of the root color in the radish. *Jap. J. Genet.* 19:99-100. (*Plant Breed. Abstr.* 21:3054. 1951.)
5. Pearson, O. H. 1930. Observations on the type of sterility in *Brassica oleracea* var. *capitata*. *Proc. Amer. Soc. Hort. Sci.* 26:34-38.
6. Pound, G. S. and D. L. Fowler. 1953. Fusarium wilt of radish in Wisconsin. *Phytopathology* 43:277-280.
7. Tatebe, T. 1938. On inheritance of root color in *Raphanus sativus*. *Jap. J. Genet.* 14:39-50. (*Plant Breed. Abstr.* 8:1633 and 9:867. 1939.)
8. Tokumasu, S. 1951. Male sterility in Japanese radish. *Sci. Bul. Facult. Agr. Kyushu Univ.* 13:83-89.
9. Williams, P. H. and G. S. Pound. 1963. Nature and inheritance of resistance to *Albugo candida* in radish. *Phytopathology* 53:1150-1154.
10. Yarnell, S. H. 1956. Cytogenetics of the vegetable crops. II. Crucifers. *Bot. Rev.* 22:81-166.

HortScience 11(2):147–148. 1976.

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

L. H. Aung
Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

Additional index words. endogenous hormones, *Lycopersicon peruvianum, Lycopersicon pimpinellifolium, Lycopersicon hirsutum,* tomato

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).

[1] Received for publication November 20, 1975. The author thanks Dr. M. Holle for a supply of tomato seeds.

Of the 3 species, *L. pimpinellifolium* had the highest content (4.3 ng $GA_{4/7}$ equiv./10 g frest wt) of GAs. This estimated value of GAs in *L. pimpinellifolium* was 44-fold and 96-fold that of *L. hirsutum* and *L. peruvianum*, respectively. Furthermore, 99% of the GAs in *L. pimpinellifolium* was in the ethyl acetate-soluble acidic fraction. In comparison, 91% of the GAs of *L. hirsutum* was in the basic fraction. In *L. peruvianum*, 30%, 60%, and 10% of the GAs were in the basic, acidic and bound fractions, respectively.

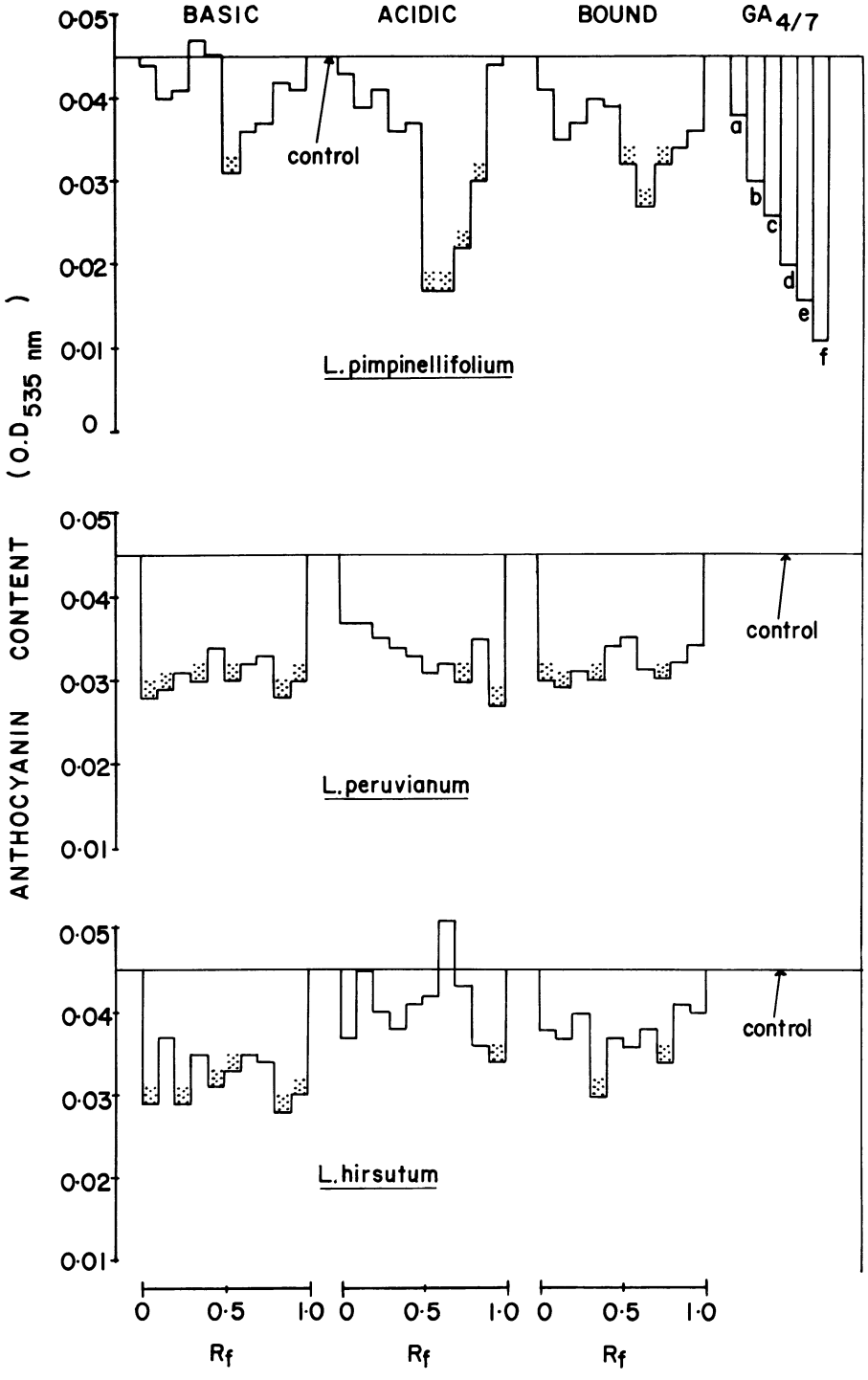

Fig. 1. The anthocyanin-decolorising activities of gibberellin-like substances in the basic, acidic, and bound fractions of 4-week old tomato shoot extracts of *Lycopersicon pimpinellifolium*, *L. peruvianum*, and *L. hirsutum* after descending paper chromatography (solvent: 10 isopropanol: 1 ammonium hydroxide: 1 water, (v/v) using the tomato hypocotyl assay (1); symbols a, b, c, d, e, and f represent 20 µl each of 10^{-12}, 10^{-11}, 10^{-10}, 10^{-9}, 10^{-8}, and 10^{-7}M of gibberellin $A_{4/7}$ respectively. Stippled regions of the histograms indicate significance from control (0.05% Tween 80) at the 5% level.

L. hirsutum has greater leaf and shoot growth than *L. peruvianum* and *L. pimpinellifolium*, but the lowest content of GAs. On the other hand, *L. pimpinellifolium* and *L. peruvianum* exhibited lesser vegetative growth, but have higher contents of GAs. These observations suggested that vegetative growth of these species may be inversely related to the content of GAs.

Comparison of the GAs content of *L. esculentum* reported in the literature (2, 3, 5, 6), and the results of the present study with 3 *Lycopersicon* species is prevented by differences in (a) extraction procedures, (b) chromatography systems, (c) bioassays and growth conditions of bioassaying, (d) kinds and age of plant materials used for extraction and (e) authentic gibberellins used as reference compounds. However, a comparison based upon results of an earlier study (1) with *L. esculentum* Mill. cv. Fireball can be made. It was estimated that about 3.0 ng $GA_{4/7}$ equiv./10 g fresh wt was present in 4-week old shoot tissues of *L. esculentum*. This value was slightly lower than the value of 4.3 ng $GA_{4/7}$ equiv./10 g fresh wt estimated for *L. pimpinellifolium*, but higher than those of *L. peruvianum* and *L. hirsutum*.

Literature Cited

1. Aung, L. H. and H. H. Bryan. 1974. Determining endogenous gibberellins in tall and dwarf tomatoes by a new tomato bioassay and chromatography. p. 52-63. *In* Y. Sumiki et al. (ed.) Plant growth substances 1973. Hirokawa Publ. Co., Inc., Tokyo, Japan.
2. Hill, T. A. and I. W. Selman. 1966. Studies on two gibberellin-like substances in young shoots of tomato (*Lycopersicon esculentum* Mill.). *J. Expt. Bot.* 17: 535 545.
3. Pegg, G. F. 1966. Changes in levels of naturally occurring gibberellin-like substances during germination of seed of *Lycopersicon esculentum* Mill. *J. Expt. Bot.* 17:214-230.
4. Perez, A. T. and W. H. Lachman. 1971. Gas-liquid chromatography of endogenous gibberellins in tomato, *Lycopersicon esculentum*. *Phytochemistry* 10:2799-2802.
5. Rajagopal, V., M. R. K. Rao, and I. M. Rao. 1974. Endogenous gibberellin and inhibitor contents in the shoot apices of tomato plants. *Current Sci.* 43:558-559.
6. Reid, D. M., A. Crozier, and B. M. R. Harvey. 1969. The effects of flooding on the export of gibberellins from the root to the shoot. *Planta* 89:376-379.