IDENTIFICATION OF HORSERADISH TYPES

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ABSTRACT.—Thirty horseradish cultivars were grouped into three types based on differences in morphological characteristics and disease reactions. Type I, known as Bohemian, has smooth lanceolate to oblanceolate radical leaves that taper acutely at the base. The plants are resistant to Turnip mosaic 1 and whiterust diseases. Type II has smooth to slightly crinkled ovate to obovate radical leaves that are rounded at the base. The plants are very susceptible to Turnip mosaic 1, expressed as a ringspot symptom, and are intermediate in resistance to white-rust. Type III, known as common, has crinkled, cordate radical leaves and is susceptible to Turnip mosaic 1, expressed as a mosaic, and to white-rust.

Horseradish, *Armoracia rusticana* Gaertn., Mey. & Scherb., is one of the oldest and best known condiments, valued for the fleshy tap-roots which have an extremely pungent flavor. Approximately 15,000,000 pounds of horseradish are processed annually for consumption in the United States, according to the National Association of Horseradish Packers. Over 1,500 acres of horseradish, or approximately 60 per cent, are grown on deep, fertile, loessial soils in the Mississippi River Valley around East St. Louis, Illinois.

Horseradish cultivars are generally divided by commercial growers and handlers into two types, "common" and "Bohemian". The common type has broad crinkled leaves and produces a root of high quality for processing. The Bohemian type has narrow smooth leaves, is more resistant to certain diseases, and generally produces a root of lower quality than the common type.

The horseradish plant is highly sterile and is propagated asexually by roots (Brzezinski, 1909 and Weber, 1949). Lack of natural seed production has reduced the possibility of developing new cultivars. Viable seeds, however, have been produced under certain controlled conditions. Brzezinski (1909) was probably the first to grow horseradish from seed. Later Weber (1949) and Moravec (1963) reported success in obtaining viable seeds. Seedlings have also been obtained during the past five years at the Illinois Agricultural Experiment Station. In evaluating seedlings and cultivars, it was evident that horseradish cultivars should be grouped into three types rather than the two types, which are commonly recognized by growers and processors.

MATERIALS AND METHODS

Data on morphological plant characteristics and disease symptoms were taken on 15 cultivars grown near East St. Louis in 1962 and 30 cultivars grown at Urbana in 1963, with 15 cultivars common to both locations.

In the East St. Louis planting, the side and crown roots were removed to promote development of a

TABLE 1. Characteristics of Horseradish Cultivars

Illinois Accession Number	Name or Source[1]	Leaf Blade Length/Width Ratio		Leaf Texture[2]	Turnip mosaic 1		White-rust[3]
		Urbana	E. St. Louis		Rating[3]	Symptom	
TYPE I (Leaf base angle less than 60°)							
105a	Russia	4.6	4.7	S	1	Black veins	1
93a	Illinois A.E.S.	4.0		S	0	None	1
104a	Russia	3.9	4.1	S	1	Black veins	1
161a	Wis. C-31	3.7		S	0	None	1
156a	Wis. E-1	3.5		S	1	Black veins	0
162a	Wis. Z-1	3.2	3.2	S	1	Black veins	1
167a	Bohemian	3.1		S	0	None	0
204a	Big Top Western	3.1	3.6	S	0	None	1
119a	Sass	3.0	3.4	S	0	None	1
142a	Wis. P-4	3.0	3.2	S	0	None	1
TYPE II (Leaf base angle 60°-90°)							
135a	Wis. Y-7	3.1		S	4	Rings	1
28a	Illinois A.E.S.	3.1		S	5	Rings	1
209a	Swiss P	3.0	3.1	S	5	Rings	0
113a	Kassa	2.9	2.9	S	4	Rings	0
208a	Swiss F	2.8	3.2	S	5	Rings	0
152a	Wis. X-1	2.8	2.7	SC	4	Rings	0
8a	Illinois A.E.S.	2.8		SC	5	Rings	0
136a	Wis. N-2	2.6		S	5	Rings	0
163a	Wis. P-15	2.4	2.7	S	3	Rings	3
131a	Wis. L-3	2.3		C	3	Rings	0

TYPE III (Leaf base angle greater than 90°)

286a	Illinois A.E.S.	2.3		C	5	Mottling	4
157a	Wis. Y-8	2.3		C	0	None	4
140a	Wis. X-9	2.2		C	0	None	0
213a	Common S	2.1		C	4	Mottling	5
138a	Wis. X-4	2.0		C	1	Black veins	0
205a	Old Jersey	2.0	2.2	C	1	Mottling	4
212a	Japan	2.0	2.3	C	5	Mottling	4
206a	Common B	2.0	2.3	C	5	Mottling	5
165a	Common J	1.9		C	4	Mottling	4
211a	Japan	1.9	2.5	C	5	Mottling	3

[1] Wisconsin (Wis.) cultivars originated from Weber's (1942) studies.
[2] Texture: S=smooth, SC=slightly crinkled, C=crinkled.
[3] Rating: 0=highly resistant, 5=highly susceptible.

large primary root, a common commercial practice. In the Urbana planting, no roots were removed. All plants were grown from root cuttings approximately 0.5 inch in diameter and 10 to 14 inches in length.

Leaf measurements were taken during September, as leaf characteristics are more pronounced and consistent at this time. For each cultivar, several mature and radical leaves were measured for length and width of the leaf blade, length of petiole, and leaf base angle. The leaf base angle is an angle subtended by arcs drawn from the midrib of the leaf blade to the basal margin of the leaf blade. Observations were made for shape, margin, and texture of the leaves. Petioles were recorded as either solid or hollow at the base of the leaf blade. Several cultivars were flowered to observe the inflorescence.

Each cultivar was rated for field susceptibility to the following diseases: White-rust, *Albugo candida* (Pers. ex Chev.) Kuntze, bacterial leaf spot, *Xanthomonas campestris* var. *armoraciae* (McCul.) Starr & Burkholder, Cercospora leaf spot, *Cercospora armoraciae* Sacc., Ramularia leaf spot, *Ramularia armoraciae* Fckl., and Turnip mosaic 1, *Marmor brassicae*.

Results and Discussion

The 30 cultivars studied were grouped into three types based on certain morphological characteristics and disease reactions of mature radical leaves. Texture, basal angle and length/width ratio of the leaf blade, together with disease susceptibility were the distinguishing characters. Others characters including differences in petiole, inflorescence, and leaf shape helped to distinguish the types. Consideration was given to combination of these characters since variations occurred within types.

Leaves. The basal angle of mature leaf blades, although difficult to measure precisely, separates Type III from Types I and II (Table 1). This angle is obtuse for Type III but acute for Types I and II. The leaf base angle is tapered for Type I (less than 60°) and rounded for Type II (between 60 and 90°) (Table 1 and Fig. 1). The length/width (L/W) ratio of the leaf blade is greatest for Type I, intermediate for Type II, and least for Type III (Table 1).

Leaf texture of Type III is distinctly crinkled, and the leaf margins are generally wavy (Fig. 1). Type I has smooth leaves and Type II has smooth to slightly crinkled leaves.

Pinnatifid leaves appeared in August and September. By October, some cultivars of Type III produced only pinnatifid leaves. Cultivars of Types I and II produced fewer pin-

Figure 1. Characteristic mature radical leaf of Type III (left), Type II (center) and Type I (right) horseradish plant.

natifid leaves than Type III, although individual exceptions occurred. This characteristic has been shown by Pound (1949) to occur in Type III at temperatures lower than 20° C. Other workers have suggested that the presence of such leaves is due to a photoperiodic response (Endo and Linn, 1960) or virus infection (Kadow and Anderson, 1946 and Novak and Vlk, 1950). However, Pound (1949) demonstrated that changing temperatures affected the leaf shape, even though 100 per cent of Type III plants were infected with mosaic virus.

In September, mature petioles of Types I and II were usually solid and petioles of Type III were usually hollow at the base of the leaf blade. In November, petioles of Types I and II tended to become hollow as the leaves reached senescence. The length of the petiole within cultivars varied with location. Observations on other leaf characteristics such as shape and margin are shown in Table 2.

Inflorescence. Horseradish flowers are arranged in paniculate racemes (Table 2). The racemes of Types I and II are uniformly elongated to form rounded panicles (Fig. 2). The lower racemes of Type III tend to elongate more than the terminal racemes, to give the inflorescence the appearance of a corymb (Fig. 2). The inflorescence of Type III frequently failed to develop and flowers aborted before opening. The inflorescence of Type III was generally smaller in size than either Type I or II. The cauline leaves, usually sessile, tended to be similar in form to the mature radical leaves.

Diseases. Although Type II is similar to Type I in some morphological respects, susceptibility of Type II to

FIGURE 2. Characteristic inflorescence of Type I (left) and Type III (right) horseradish plant.

TABLE 2. Distinguishing Characteristics of Horseradish Type

Character	Type I	Type II	Type III
LEAVES			
Shape	Lanceolate to Oblanceolate	Ovate to Obovate	Cordate
Length/width ratio	Greater than 3.0	2.4 to 3.0	Less than 2.4
Base	Tapering	Rounded to Abrupt	Cordate
Base angle	Acute (less than 60°)	Acute (60 to 90°)	Obtuse (greater than 90°)
Surface Texture	Smooth	Smooth to slightly crinkled	Crinkled
Margin	Serrate to Crenate	Crenate	Crenate
Petiole	Solid	Usually solid	Usually hollow
Pinnatifid leaves	Few late in season	Few late in season	Many late in season although variable
INFLORESCENCE			
Form	Elongated paniculate raceme	Elongated paniculate raceme	Paniculate raceme, corymbose shape
Cauline leaves	Linear to lanceolate	Lanceolate	Lanceolate to ovate, lower leaves usually pinnatifid
DISEASES			
Turnip mosaic 1	No visible symptoms	Ringspot	Mottling and chlorosis
White-rust	Resistant	Intermediate	Susceptible

Turnip mosaic 1 (*Marmor brassicae*) separated it from Type I. All plants of Types II and III surveyed have been visibly infected with Turnip mosaic 1, expressed as a ringspot in Type II and mosaic mottling in Type III (Table 1 and Fig. 3). Also, characteristic of Turnip mosaic 1 was the formation of somewhat sunken black streaks in the petioles and mid ribs, that reached the crown as the season progressed. Blackening of the smaller leaf veins occurred in some cultivars.

White-rust (*Albugo candida* (Pers. ex Chev.) Kuntze) is one of the most prevalent and destructive diseases of horseradish (Endo and Linn, 1960; and Kadow and Anderson, 1940). Cultivars of Type I possess high resistance to white-rust while cultivars of Type III are very susceptible (Table 1). Cultivars of Type II differed considerably in resistance and susceptibility and are considered intermediate between Types I and III.

Bacterial leaf spot (*Xanthomonas campestris* var. *armoraciae* (McCul) Starr & Burkholder) sometimes is quite severe. Type III proved to be very susceptible and the older leaves were completely covered with necrotic lesions following cool, rainy weather. Cultivars of Types I and II varied from highly resistant to moderately susceptible to bacterial leaf spot. This disease is questionable as a diagnostic character to identify types of horseradish.

Cercospora (*Cercospora armoraciae* Saccardo) and Ramularia (*Ramularia armoraciae* Fuckel) leaf spot diseases, generally common wherever horseradish is grown, were not prevalent or consistent enough in these plots to determine relative susceptibility and resistance of cultivars within the three types.

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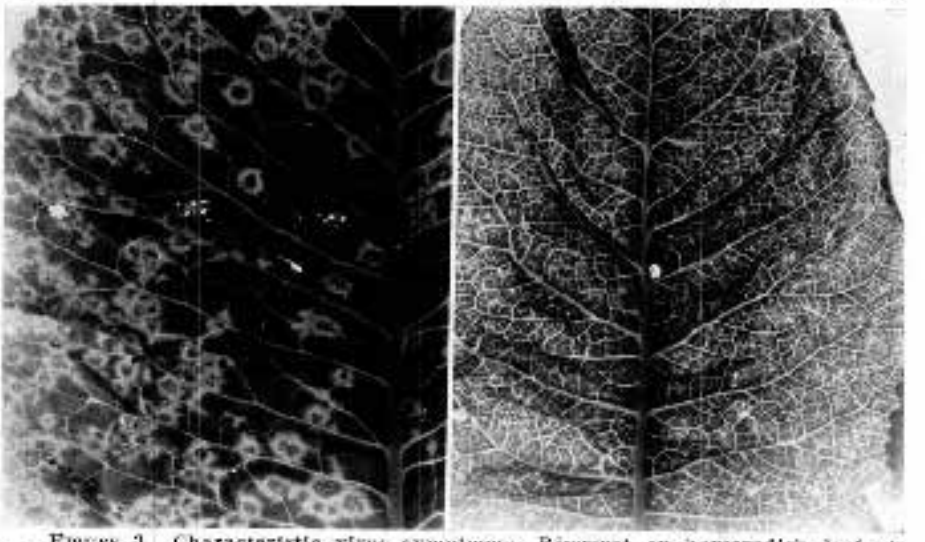

FIGURE 3. Characteristic virus symptoms: Ringspot on horseradish leaf of Type II (left) and mosaic on Type III (right).

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