

Sugar Beet Breeding Lines Combining Resistance To Bolting and Disease

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During the past ten years the California sugar beet industry has witnessed an almost complete change from open-pollinated to hybrid sugar beet varieties. Hybrids are produced by crossing a cytoplasmic male-sterile seed-bearing parent with a pollen-fertile parent. The seed-bearing parent may be the male-sterile equivalent of an inbred; an F_1 hybrid between the male-sterile line and a second inbred; or the male-sterile equivalent of an open-pollinated line. To insure complete male sterility, the seed-bearing parent must be developed from breeding lines with the Type O characteristic (3)². The pollen parent can be an inbred, an open-pollinated line, or an F_1 hybrid between two inbreds. The F_1 pollinator is produced through the use of Mendelian male sterility (4).

A major objective of the sugar beet breeding program at the U. S. Agricultural Research Station, Salinas, California, has been to develop breeding lines that possess characteristics needed in high-performing hybrid varieties. Particular attention has been given to Type O inbreds and male steriles combining resistance to bolting and curly top. Selections have been made for downy-mildew and virus-yellows resistance. The monogerm character has been incorporated into high-performing seed-bearing parents. These breeding lines have been made available to sugar beet breeders in the United States and Canada through the Beet Sugar Development Foundation.

Description of Breeding Lines

Breeding lines made available to sugar beet breeders from the U. S. Agricultural Research Station include both open-pollinated selections and inbred lines. The open-pollinated selections are all multigerm. The inbreds include both multigerm and monogerm lines. The breeding lines are designated by a combination of letters and numbers. The letter "C" refers to California, "NB" to nonbolting, "H" to cytoplasmic male sterility, and "M" to Mendelian male sterility. In the "C" series the first numeral refers to the year of seed production. The letter "C" and the first numeral have been omitted from the descriptions of the F_1 monogerm hybrids.

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² Numbers in parentheses refer to literature cited.

Open-Pollinated Selections

C361.—A Type O, bolting resistant selection from US 22/3. The line was developed by making two successive Type O selections, followed by selections for bolting resistance (1). C361 is similar to US 75 in curly-top and bolting resistance. It has been used to produce the male-sterile equivalent of C361 and as a Type O, self-sterile breeding line.

C361HO.—A male sterile produced by crossing C361 to a male-sterile plant from US 56 and backcrossing four times to C361. Increases of this male sterile have been used as the seed-bearing parent to produce commercial hybrid varieties.

C366.—The second successive bolting-resistant selection from US 35/2. This selection is superior to US 75 in sucrose percentage but inferior in root yield. It is similar to US 75 in curly-top and bolting resistance. C366 has been used as a top-cross parent in producing commercial hybrid varieties.

C663.—A pollen parent derived from a cross between US 15 and US 22/3. Selections for curly-top resistance, bolting resistance, and high sucrose content were made in the F_2 and F_4 generations. Curly-top resistance is similar to that of US 75 and bolting resistance to that of US 56. Increases of C663 have been used extensively as the top-cross parent in commercial hybrid varieties.

C585.—A bolting-resistant selection from C361. This selection combines very good bolting resistance with good curly-top resistance and has been used to produce the male-sterile equivalent of C585.

C585HO.—A bolting-resistant selection from 361HO combining very good bolting resistance with good curly-top resistance. Increases of C585HO have been used as the seed-bearing parent to produce commercial hybrid varieties.

C586.—A bolting-resistant selection from C366 combining very good bolting resistance with good curly-top resistance (2). C586 has been used to replace C366 as a top-cross parent.

C671.—A composite of Type O selections made at Salinas, California, from US 75, US 22/4, and US 56/2. The line has moderate resistance to bolting and curly top. C671 has been widely used as a Type O breeding line.

C681M.—A Mendelian male sterile of C366 which segregates approximately 50 percent aa. C681M has been used to produce four-way hybrids such as (MS of NB1 \times NB3) \times (C681M \times NB4).

C787.—A bolting-resistant selection from US 75. The selection is similar in performance and disease resistance to US 75. C787

has been used as a pollen parent to produce the commercial hybrid (MS of NB5 \times NB6) \times C787.

C951.—A Type O selection from C366, used only as a breeding line.

C952.—A Type O selection from US 15, used only as a breeding line.

C953.—A Type O selection from the European Klein E variety, used only as a breeding line.

C264.—A bolting-resistant selection from C663. Tests have shown C264 to be superior to C663 in bolting resistance but similar in other characteristics. C264 is being used as a replacement for C663.

C330.—The fifth successive selection from US 75 for resistance to virus yellows. Damage from virus yellows is only about one-half as severe in C330 as in US 75. This selection is similar to US 75 in other characteristics. C330 is being used as the pollen parent in producing experimental quantities of hybrid seed.

C321.—A yellows-resistant selection from the Type O, self-sterile line C671. Tests at Davis, California, showed C321 to be superior in yellows resistance to the parent variety and to the US commercial hybrid varieties. This selection has good resistance to bolting and curly top. C321 is being used as a yellows-resistant breeding line.

Multigerm Inbred Lines

NB1.—An increase of S_5 (Cl 179 \times Cl 1-707) combining resistance to bolting and curly top (1). Cl 179 was a Type O clone with high sucrose percentage from US 1. Cl 1-707 was a self-fertile inbred high in curly-top resistance and dark green in color. NB1 is an excellent Type O inbred with very good combining ability and has been utilized in the production of the MS of NB1 and as a breeding line.

MS of NB1.—A male sterile produced by crossing NB1 to a cytoplasmic male-sterile plant found in US 56 and then back-crossing four times to NB1 (1). MS of NB1 has been used as the seed-bearing parent to produce the F_1 hybrids MS of NB1 \times NB2, MS of NB1 \times NB3, MS of NB1 \times NB4, and MS of NB1 \times NB5. These F_1 hybrids are male sterile and have been used extensively as seed-bearing parents to produce commercial hybrid varieties.

NB2.—An inbred developed from a cross made at Salt Lake City, Utah, in 1943 between a bolting-resistant clone and a self-fertile line (2). Following intensive selection, a high-performing S_5 line was designated NB2. The inbred possesses good vigor, moderately good bolting resistance, and fair curly-top resistance. It has good combining ability especially from the

standpoint of sucrose percentage. NB2 has been used to produce the seed-bearing parent MS of $\text{NB1} \times \text{NB2}$.

NB3.—A moderately bolting-resistant segregate from the CT 9 inbred developed by Dr. F. V. Owen at Salt Lake City, Utah (2). This inbred has very good curly-top resistance but poor downy-mildew resistance. NB3 has been used to produce the seed-bearing parent MS of $\text{NB1} \times \text{NB3}$.

NB4.—An inbred developed from the same cross as NB2. This inbred combines bolting and downy-mildew resistance with good combining ability but lacks vigor and is susceptible to curly top. NB4 has been used to produce the seed-bearing parent MS of $\text{NB1} \times \text{NB4}$.

NB5.—A Type O, bolting-resistant inbred from $\text{US } 56/2 \times \text{NB1}$. This inbred has good curly-top resistance, excellent vigor, and good combining ability. NB5 has been used to produce MS of $\text{NB1} \times \text{NB5}$.

MS of NB5.—A male sterile produced by crossing NB5 to MS of NB1 and backcrossing twice to NB5 (3). Increases of MS of NB5 have been used as the seed-bearing parent to produce the F_1 hybrid MS of $\text{NB5} \times \text{NB6}$.

NB6.—An increase of S_4 ($\text{US } 22/3 \times \text{NB1}$). This inbred combines excellent bolting resistance with good curly-top resistance. NB6 has been used to produce MS of $\text{NB5} \times \text{NB6}$, the seed-bearing parent in the bolting-resistant hybrid ($\text{MS of NB5} \times \text{NB6}$) \times C787.

NB7.—An increase of S_4 (Type O $\text{US } 56/2 \times \text{NB1}$). This inbred combines very good curly-top resistance with good bolting resistance and has good combining and seed-setting ability. NB7 is being used as the pollen parent to produce commercial monogerm hybrid varieties such as $(515\text{HO} \times 569) \times \text{NB7}$ and $(562\text{HO} \times 569) \times \text{NB7}$.

C7508.—A downy-mildew resistant inbred selected from \hat{S}_2 ($\text{US } 22/3 \times \text{NB1}$). This inbred has very good bolting resistance and moderate curly-top resistance. C7508 has been used as a Type O, mildew-resistant breeding line.

C7508HO.—A male sterile produced by backcrossing four times to C7508. C7508HO has been used only as a breeding line.

C8503.—An increase of S_7 ($\text{C453} \times \text{NB1}$). This inbred has very good downy-mildew resistance, good bolting resistance, and fair curly-top resistance. C8503 has been used as a source of mildew resistance.

C884.—The second successive bolting-resistant selection from US 201B. C884 has been used as a breeding line combining bolting and leaf-spot resistance.

Monogerm Inbred Lines

C7507.—An increase of S_4 (US 22/3 \times SLC 101mm). This inbred has very good bolting resistance, medium vigor, and good seed-setting ability, but lacks curly-top resistance. Although the inbred is not completely Type O, pollen producers do not occur in hybrids with good cytoplasmic male steriles. C7507 has been used to produce the seed-bearing parents 515HO \times 507 and 569HO \times 507.

C7515.—An increase of S_5 (NB1 \times SLC 101mm). This inbred has good bolting resistance, good vigor, and fair seed-setting ability, but lacks curly-top resistance. It is a very good Type O line with good combining ability. C7515 has been used to produce the male-sterile C7515HO.

C7515HO.—A male sterile produced by crossing C7515 to MS of NB1 and then backcrossing four times to C7515. Increases of C7515HO have been used as the seed-bearing parent to produce the F_1 hybrids 515HO \times 507, 515HO \times 569, 515HO \times 561, and 515HO \times 562. These F_1 hybrids have been used as seed-bearing parents to produce commercial monogerm hybrid varieties.

C7569.—An increase of S_3 (NB1 \times SLC 101mm). This monogerm inbred has good bolting, medium vigor, good seed-setting ability, and moderate curly-top resistance. Although the inbred is not completely Type O, pollen producers do not occur in hybrids with good cytoplasmic male steriles. C7569 has been used to produce the monogerm seed-bearing parents 515HO \times 569, 561HO \times 569, and 562HO \times 569.

C8569HO.—C7569 crossed to a cytoplasmic male sterile from MS of NB1 and backcrossed to C7569. Increases of C8569HO have been used as the seed-bearing parent to produce commercial monogerm hybrid varieties.

C9561.—A bolting-resistant monogerm inbred from S_1 (NB1 \times C7507). This inbred has good bolting resistance, fair curly-top resistance, good seed-setting ability, and is a good Type O. C9561 has been used to produce the seed-bearing parents 515HO \times 561 and 569HO \times 561.

C9561HO.—A male sterile produced by backcrossing to C9561. Increases of 9561HO have been used as the seed-bearing parent to produce 561HO \times 569.

C0562.—A Type O sister line of C9561. This monogerm inbred combines good bolting and curly-top resistance with good combining ability. C0562 has been used to produce the male sterile C0562HO.

C0562HO.—A male sterile produced by backcrossing twice to C0562. Increases of C0562HO have been used as the seed-bearing parent to produce 562HO \times 569, 562HO \times 546, and 562HO \times 549.

C1546.—An increase of S_2 (C7507 \times NB6). This inbred has good resistance to curly top and bolting. Although not completely Type O, pollen producers do not occur in crosses with good cytoplasmic male steriles. C1546 has been used to produce the seed-bearing parent 562HO \times 546.

C2563.—A curly-top resistant selection from C0562. Curly-top and bolting resistance are superior to that of C0562 and similar to that of NB1. C2563 has been used to produce the male sterile C2563HO.

C2563HO.—A male sterile produced by backcrossing twice to C2563. This male sterile has been used as the seed-bearing parent to produce F_1 hybrids high in curly-top and bolting resistance such as 563HO \times 546.

C2549.—A bolting-resistant sister line of C1546. This inbred is similar to C1546 in curly-top resistance. C2549 is not completely Type O but yields male-sterile progeny when crossed with good male steriles such as 562HO.

C3550.—A curly-top resistant selection from S_4 (C7507 \times NB6). This is a sister line of C1546 and C2549. It is superior to both C1546 and C2549 in curly-top resistance and to C1546 in bolting resistance. C3550 has been used as the pollen parent to produce F_1 hybrids such as 563HO \times 550.

C3550HO.—A male sterile produced by backcrossing to a segregate of C7507 \times NB6. C3550HO is being used to produce the male-sterile equivalent of C3550.

C3505.—The second backcross of a monogerm inbred to the high-performing NB1 multigerm inbred. This Type O inbred combines good resistance to bolting and curly top. C3505 is being used as a breeding line.

C2648-3.—An increase of a leaf-spot-resistant selection made at Fort Collins, Colorado, from S_3 (673-2 \times C7507). 673-2 is a Type O plant found at Salinas, California, in polycross selections from US 401. C2648-3 has moderate leaf-spot resistance but lacks curly-top and bolting resistance. It is being used as a leaf-spot-resistant inbred parent and as a breeding line.

C2648-11.—Bolting-resistant sister line of C2648-3. C2648-11 is being tested as an inbred parent in hybrids requiring bolting and leaf-spot resistance.

C3534.—A curly-top resistant, Type O, monogerm inbred selected from a cross between NB1 and C2563. Greenhouse tests have shown C3534 to be equal or superior to C2563 in curly-

top resistance. Bolting resistance is very good. C3534 is being tested as a curly-top-resistant monogerm inbred parent.

C3534H4.—A male sterile from a cross between C2563HO and C3534. C3534H4 is being used as the seed-bearing parent to produce the male-sterile equivalent of C3534.

Utilization of Seed Releases

Breeding lines developed by the U. S. Department of Agriculture at Salinas, California, have been used as parents in the production of both US and sugar company hybrid varieties. Seed production records furnished by Mr. S. C. Campbell, Manager, West Coast Beet Seed Company, show that between 1958 and 1963 approximately 15,283,000 pounds of sugar beet seed were

Table 1.—Utilization of sugar beet breeding lines developed by the U. S. Department of Agriculture, Salinas, California, in the production of commercial hybrid seed from 1958 to 1963.

Seed-bearing parent	Pollen parent	Seed production pounds
Multigerm seed		
MS of NB1 × NB2	C366	47,500
MS of NB1 × NB2	C586	599,300
MS of NB1 × NB2	C681M × NB4	800
MS of NB1 × NB3	C586	84,900
MS of NB1 × NB3	C663	854,800
MS of NB1 × NB3	C681M × NB4	1,000
MS of NB1 × NB4	C366	14,100
MS of NB1 × NB4	C586	247,200
MS of NB1 × NB4	C663	210,100
MS of NB1 × NB5	C663	418,400
MS of NB5 × NB6	C787	18,900
C361HO	Company pollinators	1,887,800
C585HO	Company pollinators	957,500
MS of NB1 × NB2	Company pollinators	84,300
MS of NB1 × NB3	Company pollinators	2,629,300
MS of NB1 × NB4	Company pollinators	372,300
MS of NB1 × NB5	Company pollinators	363,800
	Total	8,792,300
Monogerm seed		
515HO × 507	C663	1,400
515HO × 561	C663	2,300
515HO × 569	C663	49,000
569HO × 507	C663	2,000
562HO × 569	C663	37,700
515HO × 569	NB7	39,800
562HO × 569	NB7	34,900
569HO	NB7	900
569HO	Company pollinators	1,153,600
562HO	Company pollinators	9,800
561HO × 562	Company pollinators	198,200
562HO × 569	Company pollinators	386,900
	Total	1,916,500

produced for use in California and Nevada. Included were 2,665,000 pounds of US hybrid seed and 8,044,000 pounds of sugar company hybrid seed involving male-sterile parents developed by the U. S. Department of Agriculture. Utilization of the seed releases in commercial hybrids is summarized in Table 1.

Acknowledgments

Source material for many of the breeding lines was furnished in 1947 by Dr. F. V. Owen and associates of the U. S. Sugar Beet Investigations Laboratory, Salt Lake City, Utah. Dr. V. F. Savitsky of the Salt Lake City Laboratory furnished the original SLC 101 monogerm line. Mr. Dewey Stewart and associates of the U. S. Sugar Beet Investigations office in Beltsville, Maryland, furnished the US 401 lines.

Curly-top resistance evaluations and selections were made by Mr. A. M. Murphy at the U. S. Sugar Beet Field Laboratory, Twin Falls, Idaho, and the Crops Research Laboratory, Logan, Utah. Dr. C. W. Bennett also made curly-top resistance evaluations in the greenhouse at Salinas. Mr. J. O. Gaskill of the U. S. Sugar Beet Field Laboratory, Fort Collins, Colorado, made leaf-spot resistance selections and evaluated the resistance of C2648-3 and C2648-11.

Variety performance tests were made by Mr. Charles Price and associates, and by Mr. K. D. Beatty, at the U. S. Southwestern Irrigation Field Station, Brawley, California. Varieties were also evaluated in each of the major sugar beet growing areas of California by the American Crystal Sugar Company, Holly Sugar Corporation, Spreckels Sugar Company, and Union Sugar Division, Consolidated Foods Corporation. Seed production tests were made by the West Coast Beet Seed Company, Salem, Oregon.

The Agronomy and Plant Pathology departments of the University of California, Davis, cooperated in tests to determine the yellows resistance of C330 and C321.

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