FACTORS AFFECTING SURVIVAL OF WINTER OATS

Technical Bulletin No. 1346

Agricultural Research Service

U.S. DEPARTMENT OF AGRICULTURE

CONTENTS

Washington, D.C. Issued October 1965

FACTORS AFFECTING SURVIVAL OF WINTER OATS[1]

By FRANKLIN A. COFFMAN, *retired, Crops Research Division, Agricultural Research Service*

INTRODUCTION

The most important plant character in the production of fall-sown oats is winter hardiness. Factors that influence the extent of winter-killing are: (1) The variety grown; (2) winter temperature; (3) altitude, which includes chances for protective snow cover; (4) soil type; (5) winter moisture, which includes geographic area; and (6) the presence of soilborne mosaic.

HISTORY AND SCOPE OF TESTS

The Uniform Winter Oat Hardiness Nursery was started in 1926. All oats were grown in experimental plots by the U.S. Department of Agriculture in cooperation with State agricultural experiment stations of the United States and the Provinces of the Dominion of Canada. Data have been assembled for 1 to 36 years from 114 locations in 29 States of the United States and from 5 locations in 2 Provinces in Canada (equivalent to 1,249 station years). All entries survived 100 percent in all years at 6 locations. All were 100 percent killed in all years at 4 locations, and killing of a differential nature was reported from 109 locations. Results of some aspects of these investigations have been published (*3–16*).[2] This report summarizes data obtained over a 36-year period.

All major winter oat types and nearly all winter oat varieties released to growers in North America during the 36-year period were included for 1 or more years in the nurseries. Data have been recorded not only on named varieties but also on numerous selections, many of hybrid origin.

To present all data obtained on the 342 entries grown was impracticable. Thus, this bulletin includes summary data on seven varieties, Appler, Fulghum, Hairy Culberson, Lee, Pentagon, Tech, and Winter Turf (check), grown for 36 years, Wintok grown for 24 years,[3] and Fulwin for 26 years. The data on the nine varieties

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[1] Cooperative investigations of the U.S. Department of Agriculture and the experiment stations listed in table 1. The author is indebted to each of the cooperators listed, who supplied data on winter hardiness nurseries grown on their respective stations.

[2] Italic numbers in parentheses refer to Literature Cited, p. 27.

[3] Data on parent variety Hairy Culberson, only slightly less hardy, was substituted for missing data on Wintok for the years 1937 and 1945 since there was little winterkilling in those 2 years.

evaluate the effect of different factors on survival of winter oats in North America.

Table 1 lists the cooperating States and stations, their location (fig. 1), altitude (*22*), soil type, winter temperature zone, years grown, and cooperators reporting data. Similar data are also listed for five locations in two Provinces of the Dominion of Canada.

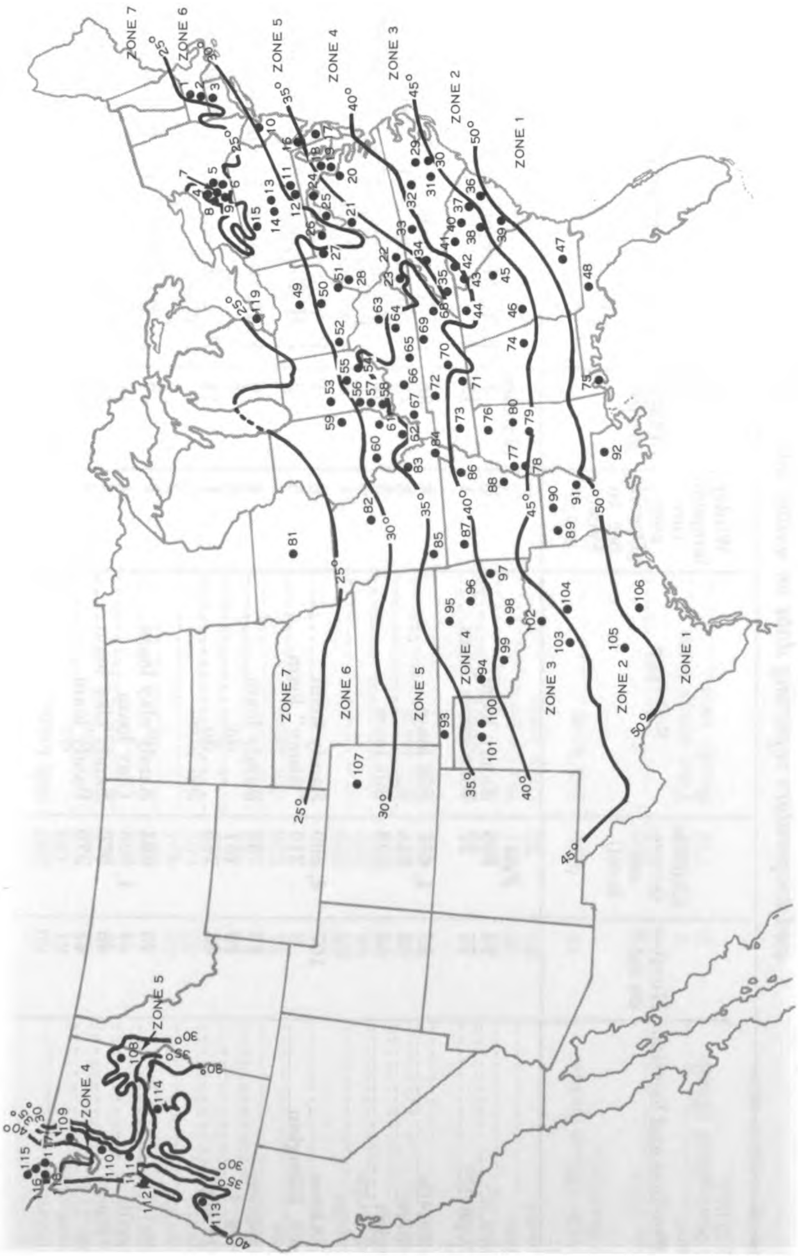

FIGURE 1.—Average winter temperature zones and location of stations cooperating in the Uniform Winter Oat Hardiness Nursery, 1926–62.

TABLE 1.—*Cooperating States and Provinces, location (fig. 1), altitude, soil type, winter temperature zone, years grown, and cooperators reporting data on winter oats, 1926–62*

State or Province and location	Number on fig. 1	Altitude (above sea level)	Soil type	Winter temperature zone (December to February) [1]	Years grown	Cooperators by State
		Feet			*Number*	
Alabama:						
Auburn	74	698	Sandy loam	3	1	E. L. Mayton, H. F. Yates.
Fairhope	75	57	Fine sandy loam	1	13	
Arkansas:						
Fayetteville	87	1,451	Silt loam	4	35	C. R. Adair, Tildon Easley, T. H. Johnston, C. K. McClelland, H. R. Rosen, K. Smith, R. L. Thurman, E. F. Vestal, J. W. White, F. J. Williams, W. J. Wiser.
Jonesboro	86	345		3	1	
Stuttgart	88	228	Silt loam	3	32	
Colorado, Akron	107	4,560	Sandy loam	6	4	F. W. Frazier, G. O. Hinze.
Connecticut, Ellington	3	219	"Stony" loam	6	2	I. K. Bespalow, E. K. Walrath.
Delaware:						
Georgetown	17	54	Sandy loam	4	2	F. D. Blest, F. B. Springer, Jr.
Newark	16	137	do	5	6	
Florida, Quincy	48	260	do	1	14	R. C. Bond, W. H. Chapman, J. D. Warner.
Georgia:						
Athens	45	694	Sandy clay loam	3	19	J. E. Bailey, R. P. Bledsoe, Acton Brown, R. R. Childs, J. W. Dobson, Hugh Dozier, C. D. Fisher, H. S. Garrison, U. R. Gore, S. J. Hadden, J. W. Johnson, Harold Loden, D. D. Morey, L. N. Skold.
Blairsville	44	1,926	Clay loam	4	17	
Experiment	46	975	Sandy clay loam	3	36	
Tifton	47	370	Sandy loam	1	10	

Illinois:						
Alhambra	60	563	Silt loam	5	5	C. M. Brown, D. R. Browning, G. H. Dungan, J. W. Pendleton, Ed Sullivan, J. P. Varra, R. O. Weibel.
Brownstown	61	403	do	5	8	
Carbondale	62	416	do	5	10	
Urbana	59	725	do	6	17	
Indiana:						
Bedford	54	681	do	5	9	R. M. Caldwell, L. E. Compton, H. G. Hall, F. L. Patterson, J. F. Schafer.
Evansville	58	431		5	2	
Lafayette	53	661	Silt loam	6	19	
Princeton	57	481		5	8	
Vincennes	56	431		5	2	
Worthington	55	540		5	3	
Iowa, Ames	81	926	Silt loam	7	8	K. J. Frey, R. Grindeland, H. C. Murphy.
Kentucky:						
Allensville	65	579		4	4	V. C. Finkner, L. M. Josephson, D. A. Reid, Randolph Richards, J. F. Shane.
Hopkinsville	66	521		4	6	
Lebanon	64	779		4	2	
Lexington	63	989	Silt loam	5	19	
Princeton	67	455		4	6	
Louisiana:						
Baton Rouge	92	35	Silt loam	1	14	E. C. Bashaw, J. P. Gray, C. B. Haddon, J. A. Hendrix, D. M. Johns, J. Y. Oakes, Sidney Stewart.
Bosier City	89	180		2	2	
Calhoun	90	171	Sandy loam	2	13	
St. Joseph	91	76	Clay loam	2	6	
Maryland:						
Beltsville (Plant Industry Station).	18	330	Silt loam	4	22	W. S. Becker, F. A. Coffman, Wendell Headley, C. V. Lowther, C. B. Marcus, R. G. Rothgeb, Roger Smith, J. W. Taylor.
College Park	19	170	do	4	21	
Massachusetts:						
Amherst	1	267	Fine sandy loam	6	1	I. K. Bespalow, W. A. Rosenau, E. K. Walrath.
West Springfield (Feeding Hills).	2	119	Sandy loam	6	12	

See footnotes at end of table.

TABLE 1.—*Cooperating States and Provinces, location (fig. 1), altitude, soil type, winter temperature zone, years grown, and cooperators reporting data on winter oats, 1926–62*—Continued

State or Province and location	Number on fig. 1	Altitude (above sea level)	Soil type	Winter temperature zone (December to February) [1]	Years grown	Cooperators by State
		Feet			*Number*	
Mississippi:						
Holly Springs	76	600	Silt loam	3	16	T. F. Akers, B. L. Arnold, D. H. Bowman, R. B. Carr, S. C. Clapp, J. M. Green, P. W. Gull, G. F. Henry, S. S. Ivanoff, J. W. Neely, J. F. O'Kelly, P. G. Rothman, A. D. Smith, A. D. Suttle, H. A. York.
Scott	77	136	do	3	1	
State College	79	362	Houston black clay	3	34	
Stoneville	78	122	Fine sandy loam	3	33	
West Point	80	241	Houston black clay	3	16	
Missouri:						
Columbia	82	738	Silt loam	6	24	B. M. King, C. O. Luper, M. E. Michaelson, J. M. Poehlman, Dale Sechler.
Perry County (Gerardeau).	83	356	do	4	1	
Pierce City	85	1, 198	do	4	2	
Sikeston	84	328	Sandy loam	4	15	
New Jersey, New Brunswick	10	61	do	5	28	G. H. Ahlgren, C. S. Garrison, Steve Lund, R. S. Snell, E. L. Spencer, H. B. Sprague.
New York:						
Aurora	4	436		7	2	N. F. Jensen, E. J. Kinbacher, H. H. Love.
Caldwell (field) (Ithaca)	6	836		7	1	
Ithaca (New York Experiment Station).	9	836	Clay loam	7	10	
Katola (field) (Ithaca)	7	836		7	1	
McGowan (field) (Ithaca)	8	836		7	1	
Mount Pleasant	5	[2] 713		7	1	

North Carolina:						
McCullers	30	384	Sandy loam	3	1	E. S. Carr, J. M. Carr, W. H. Chapman,
Raleigh	29	376	do	3	5	H. R. Clapp, G. M. Garren, T. T.
Rowan County	31	342		3	2	Hebert, J. W. Hendricks, P. H. Kime,
Salisbury	32	760		3	4	G. K. Middleton, C. F. Murphy, J. L.
Statesville	33	926	Clay loam	3	24	Rand.
Swannanoa	34	2,522	Balfor loam	4	6	
Waynesville	35	2,756	Clay loam	4	18	
Ohio:						
Carpenter (Harrisonville)	51	658	Silt loam	5	1	W. P. Byrd, V. C. Finkner, James
Columbus	50	824	do	5	14	Foster, J. M. Hamill, C. A. Lamb,
Germantown	52	713	do	5	12	L. S. Powelson, D. A. Ray.
Wooster	49	920	do	6	7	
Oklahoma:						
Cherokee	95	1,175	Very fine sandy loam	4	5	H. F. Cobb, C. B. Cross, B. C. Curtis,
Goodwell	93	3,286	Silt loam	5	3	R. G. Dahms, V. C. Hubbard, C. H.
Heavener	97	561	Sandy loam	3	2	Jameson, T. H. Johnston, R. E.
Lawton	99	1,111	Silt loam	3	15	Odom, W. M. Osborn, A. M. Schlehu-
Lone Grove	98	872	Sandy loam	3	6	ber, J. B. Sieglinger, G. W. Statton,
Stillwater	96	870	Silt loam	4	27	Edmund Stephens, O. C. Terry.
Woodward	94	1,893	Very fine sandy loam	4	29	
Oregon:						
Astoria	112	20	Silty clay loam	4	5	R. E. Fore, W. E. Hall, D. D. Hill, H. B.
Corvallis	113	319	Silt loam	4	6	Howell, Roderick Sprague.
Moro	114	200	Very fine sandy loam	5	11	
Pennsylvania:						
Centre Hall	13	1,100		6	5	C. S. Bryner, F. A. Coffman, E. A.
Clearfield	15	1,100		6	6	Hockett, H. G. Marshall, R. P.
Lancaster	11	413		5	1	Pfeifer.
Landisville	12	405		5	5	
State College	14	1,191	Silt to silty clay loam	6	5	

See footnotes at end of table.

TABLE 1.—*Cooperating States and Provinces, location (fig. 1), altitude, soil type, winter temperature zone, years grown, and cooperators reporting data on winter oats, 1926–62*—Continued

State or Province and location	Number on fig. 1	Altitude (above sea level)	Soil type	Winter temperature zone (December to February) [1]	Years grown	Cooperators by State
		Feet			*Number*	
South Carolina:						
Blackville	39	296	Sandy loam	2	5	T. S. Buie, W. P. Byrd, R. B. Carr, R. S. Cathcart, H. P. Cooper, R. W. Earhart, E. B. Eskew, S. J. Hadden, E. E. Hall, R. W. Hamilton, H. F. Harrison, J. H. Hoyert, J. A. Keaton, G. B. Killinger, J. W. Neely, W. R. Paden, B. E. G. Prichard, J. J. Stanton, R. W. Wallace, H. W. Webb, G. J. Wilds.
Chester	40	537	Sandy clay loam	3	8	
Clemson	42	850	Sandy loam	4	34	
Columbia	38	351	do	3	2	
Florence	36	136	do	2	2	
Hartsville	37	227	Fine sandy loam	3	34	
Westminster	43	953	Clay loam	4	10	
York	41	680	do	3	4	
Tennessee:						
Columbia	71	656	Silt loam	3	5	J. Adams, J. J. Bird, E. J. Chapman, E. S. Chapman, J. A. Ewing, N. I. Hancock, B. P. Hazelwood, L. R. Neal, J. A. Odom, J. N. Odom, H. P. Ogden, E. L. Smith, Lester Weakley.
Crossville	70	1,881	do	4	20	
Greenville	68	1,581	do	4	2	
Jackson	73	425	do	3	11	
Knoxville	69	1,004	do	4	33	
Springfield	72	595	do	4	1	

Texas:						
Amarillo	100	3, 676	Clay loam	4	11	I. M. Atkins, P. B. Dunkle, Henry Dunlavy, A. M. Ferguson, J. H. Gardenhire, H. O. Hill. D. R. Hooten, C. H. McDowell, E. S. McFadden, H. C. McNamara, G. T. McNess, P. C. Mangelsdorf, D. D. Porter, K. B. Porter, H. E. Rea, D. A. Reid, G. W. Rivers, D. E. Weibel, R. E. Wester.
Bushland	101	3, 825	Silty clay loam	4	9	
College Station	106	360	Fine sandy loam	1	23	
Denton	103	620	Clay loam	3	34	
Greenville	104	552	Houston Black Clay	2	32	
Howe	102	846	do	3	1	
Temple	105	630	do	2	13	
Virginia:						
Arlington	20	44	Silt loam	4	13	W. S. Becker, F. A. Coffman, Horace Garth, P. T. Gish, M. S. Kipps, R. W. Perkins, C. W. Ryburn, E. Shulkcum, T. M. Starling, Frank Stevenson, J. W. Taylor, R. E. Wester.
Blacksburg	22	2, 100	do	5	26	
Glade Spring	23	2, 074	do	5	11	
Staunton	21	1, 380	do	5	10	
Washington:						
Battle Ground	111	[2] 100		4	3	O. E. Barbee, Karl Baur, M. S. Grunder, H. E. Harndon, W. Perry.
Mount Vernon	109	23		4	3	
Pullman	108	2, 550	Silt loam	5	4	
Puyallup	110	49		4	5	
West Virginia:						
Kearneysville	24	589	Silt loam	5	3	C. J. Cunningham, T. C. McIlvaine, G. G. Pohlman, B. C. Ritter, Collins Veatch, J. W. Taylor, R. O. Weibel.
Lakin	28	553	do	5	5	
Morgantown	27	963	do	5	19	
Reedsville	26	1, 817		6	7	
Wardensville	25	[2] 927	Fine sandy loam	5	9	
Canada, British Columbia:						
Cobble Hill	117	(3)		4	3	R. H. Turley.
Duncan	116	(3)		4	2	
Nanaimo	115	(3)		4	1	
Saanichton	118	(3)		4	7	
Canada, Ontario, Harrow	119	[2] 600		7	2	G. H. Clark.

[1] Average (December to February) winter temperatures in zones 1 to 7, inclusive, were 50° F. and above, 45°–50° F., 40°–45° F., 35°–40° F., 30°–35° F., 25°–30° F., and 25° F. and below, respectively.

[2] Approximate: based on altitude at nearby location.

[3] Below 200.

MORPHOLOGIC CHARACTERS AND HISTORY OF VARIETIES TESTED

Among the nine varieties reported in this study are representatives of each of the major winter oat varietal types grown on farms in North America during the 36-year period. Morphologic descriptions and, in part, histories of each of these oats have been published (*12, 13, 15, 16, 20, 23*). Four primary morphologic characters of the nine winter oat varieties in this study are reported in table 2.

Except for Winter Turf (C.I. 3296),[4] the histories of these nine varieties have been traced. Winter Turf is also known as Winter Gray or Gray Winter, Virginia Gray, and Oregon Gray Winter. It would seem the oat was grown in Virginia long before 1900. Seed of Gray Winter (C.I. 8) was first received by the U.S. Department of Agriculture apparently in 1900 from Peter Henderson & Co., Garrett Park, Md., who had obtained seed from Germany in 1895. As oats of this type had been grown in England and Germany for many decades before 1900, Gray Winter probably was introduced into Virginia from England, or at least from Europe, possibly a century or more ago. The variety has been comparatively homozygous for decades. It matures considerably later than any of the other well-known winter oats grown in America. This late maturing eliminates chances for it to be subject to natural hybridization.

The primary source of winter oat varieties in America has been the old variety known by several names, such as Red Texas, Texas Rustproof, and Red Rustproof.

TABLE 2.—*Four primary morphologic characters of 9 winter oat varieties reported in study*

Variety	C.I. No.	Maturity	Height	Lemma color	Awns
Appler	1815	Midlate	Medium	Red	Straight.
Fulghum	708	Early	do	do	Variable.
Fulwin	3168	Midearly	Tall	do	Do.
Hairy Culberson.	2505	do	Medium	Gray	Do.
Lee	2042	Midlate	Tall	Yellow	Few straight.
Pentagon	2499	Midearly	do	Red	Variable.
Tech	947	Early	Medium	Black	Few straight.
Winter Turf	3296	Very late	Very tall	Gray	Twisted.
Wintok	3424	Early	Short	do	Few straight.

One story (*21*) of the origin or introduction of that old variety into the United States was obtained by U. R. Gore from the records of the Transactions of the Georgia State Agricultural Society for 1876. The story indicates that a soldier returning to South Carolina from the Mexican War (1848 or 1849) brought back from Mexico seed of a so-called Mexican Red Rustproof oat and that Red Rustproof was the result.

[4] C.I. refers to accession number of Cereal Crops Research Branch, Crops Research Division, Agricultural Research Service.

G. W. Hendry, of California, obtained oat seeds from adobe bricks taken from the ruins of a Spanish mission built in Mexico in 1780, as well as from ruins of other missions built somewhat later in California. Hendry sent oat seeds obtained from those bricks to F. A. Coffman for identification. Some were of the usual Red Rustproof type. Thus, such oats were present in North America more than 180 years ago. It can be assumed they were also introduced into America from Spain or at least from the Mediterranean region.

Fields of unimproved Red Rustproof oats were observed nearly 40 years ago throughout Southern United States. Many fields were almost a hodgepodge of different oat types. The morphologic type typified by Appler (C.I. 1815) was dominant, but oats with red, gray, some black, and yellow kernels were seen. The plants differed greatly in height and maturity, in type of awns, and in panicle shape. This explains why it has been possible to obtain so many widely differing oats from Red Texas, or, as the story found by U. R. Gore would indicate, the Mexican Red Rustproof variety.

According to T. R. Stanton (*23*), Appler, typical of Red Rustproof and the dominant type in the mixed variety, was selected by J. E. Appler, of Georgia. Stanton does not give the probable date it was selected. U.S. Department of Agriculture records, however, reveal that Appler was first received from the Alexander Seed Co., Augusta, Ga., in September 1902.

J. A. Fulghum, of Georgia, selected Fulghum from the old Red Rustproof in 1892. In 1912, C. W. Warburton received seed of Fulghum oats (C.I. 699) from E. F. Cauthen, of Alabama. In 1920, T. R. Stanton reselected Fulghum at the Arlington Experiment Farm of the U.S. Department of Agriculture in Virginia, and among other selections obtained Pentagon (C.I. 2499) and Winter Fulghum (C.I. 2500).

In 1930, N. I. Hancock, of Tennessee, noted that Pentagon was not homozygous and from it he selected Fulwin (C.I. 3168) and several other varieties.

In 1909, C. W. Warburton, working in Virginia, selected Aurora (C.I. 831) from Appler. Aurora was used by T. R. Stanton as a parent of his Winter Turf × Aurora cross made in 1916 at Arlington, Va. From among the progeny of that cross Stanton selected Lee (C.I. 2042) in 1918. Lee was the first winter oat of known hybrid origin produced in America, and possibly the first in the world. It has been much used in crossing to produce other winter oat varieties.

One of the early agronomists of a Southern State told the following story of how Culberson (C.I. 273) was produced. After an exceptionally severe winter, only a few scattered plants survived in a field of old Red Rustproof oats. These plants were saved "in bulk" by a man named Culberson, and the Culberson variety was the result. The date of selection is not known, but records reveal that seeds of Culberson oats were received by the U.S. Department of Agriculture from a seed firm of Dallas, Tex., as early as March 9, 1903.

According to several publications that appeared about 50 years ago, Culberson was not homozygous. This is further proved by the fact that Dwarf Culberson (C.I. 748) was selected from it by C. A. Mooers, of Tennessee, in 1906 and Hairy Culberson (C.I. 2505) was selected by T. R. Stanton at Arlington, Va., about 50 years ago. The strain of Culberson used by the U.S. Department of Agriculture was received from North Carolina in 1904. Hairy Culberson is characterized by short, fine setaceous hairs in the juvenile stage (*23*).

Tech (C.I. 947), an entirely different type, has black kernels and was selected from Culberson by T. B. Hutcheson at Blacksburg, Va.

Wintok (C.I. 3424) was selected by C. B. Cross at Stillwater, Okla., from a bulk population of progeny of the cross Hairy Culberson × Winter Fulghum made by W. D. Mankin, a field assistant of the U.S. Department of Agriculture, working at Arlington, Va.

Hence, records indicate clearly that, except for Winter Turf, all of the varieties on which data are presented in this bulletin trace either by selection or hybridization to the old Red Rustproof oats in America.

EXPERIMENTAL PROCEDURE

Throughout the 36 years for which data were compiled, all seed for growing the winter hardiness nurseries was prepared at and mailed from the Washington, D.C., area. Seed for sowing the nine varieties on which data are presented was grown at the Arlington Experiment Farm in Virginia from 1926 to 1942. From 1943 to 1961 seed was grown primarily at the Plant Industry Station, Beltsville, Md. To augment seed supplies from time to time, especially those of the less hardy oats, seed has also been grown at the Aberdeen substation, Aberdeen, Idaho. The seed was grown from fall-sown oats in Virginia and Maryland and from spring-sown oats at Aberdeen, Idaho. The first year Fulwin was included in the nurseries, 1936–37, its seed was received from N. I. Hancock, of Knoxville, Tenn.; and the first year Wintok was included, 1937–38, its seed was received from C. B. Cross, of Stillwater, Okla.

During the first 10 years of these experiments, 100 kernels of each entry were space planted, usually at intervals of about 2 inches in rows 17 to 18 feet long. From 1937 to 1941, 100 kernels of each entry were space planted in two rows, 50 kernels per row. After 1941, the nurseries at only the more southern stations were sown with seeds that had been counted; seeds for the other stations were weighed. After 1945 none of the seeds were counted, and seed for all nurseries was weighed. All nurseries sown with weighed seed have been seeded in duplicate 5-foot rows, with 5 grams of seed per row. Some cooperators have used randomization in seeding these nurseries; others have not.

In nurseries sown with counted seeds the percentages of survival were calculated on the basis of actual counts of plants made in the fall after the plants had emerged and again in the spring after danger of killing freezes had passed. This procedure posed no problem in the fall, but at some locations the plants had grown so much during the winter it was necessary to spade up and separate them to make spring counts.

When 5-gram lots of seed were sown, survival percentages were calculated from two carefully made estimates of stands—the first in the fall before severe winter started, and the second in the spring after danger of killing had passed.

RESULTS

Survival of Varieties

Table 3 indicates the number of nurseries grown each year, the number in which no killing was observed, the number in which all entries were killed, and the number of nurseries in which differential killing was reported and the average percentage of survival of the varieties in those nurseries.

Throughout the 36-year period, the survival of Winter Turf, which at the start of these nurseries was considered America's most hardy oat, has been used as a basis or check for measuring the comparative hardiness of other oats tested. In all comparisons, the survival of the check has been considered 100 percent.

The data indicate the decided superiority of Wintok in hardiness.

TABLE 3.—*Annual and average survival of winter oat varieties grown in Uniform Winter Oat Hardiness Nursery during the 36-year period 1926–62*

Year grown	Total reports received	Nurseries where—			Survival of varieties tested								
		All entries survived	No entries survived	Differential killing was reported	Winter Turf (check)	Appler	Fulghum	Lee	Tech	Pentagon	Hairy Culberson	Fulwin	Wintok
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1927	7	2	0	5	56.0	63.3	53.3	51.3	53.5	60.9	62.6	------	------
1928	9	0	3	6	23.7	43.5	44.9	25.8	40.8	27.6	60.9	------	------
1929	10	1	0	9	85.9	87.6	81.6	85.2	81.0	87.1	86.4	------	------
1930	14	0	4	10	22.1	23.8	17.9	24.5	31.7	28.3	36.5	------	------
1931	15	5	0	10	91.6	92.2	88.1	89.8	88.1	91.7	90.0	------	------
1932	23	4	0	19	89.9	84.6	75.9	91.3	81.8	90.8	87.7	------	------
1933	25	1	4	20	76.9	68.0	63.5	74.7	75.3	74.9	81.4	------	------
1934	21	2	2	17	77.8	79.6	70.1	80.9	77.4	80.2	82.2	------	------
1935	25	0	6	19	72.5	61.6	63.5	68.1	68.7	70.9	75.2	------	------
1936	26	1	2	23	52.4	44.2	48.2	48.8	52.7	57.6	56.5	------	------
1937	29	5	2	22	83.5	74.4	88.0	83.8	86.1	85.7	88.1	91.2	(1)
1938	36	3	2	31	67.6	58.4	70.0	62.0	68.1	71.4	71.3	76.1	75.1
1939	31	5	2	24	79.9	70.3	77.4	76.4	76.6	77.0	77.2	80.2	78.7
1940	32	1	2	29	72.2	59.5	70.9	70.2	73.4	72.3	75.3	74.5	77.6
1941	35	4	2	29	58.5	53.7	65.7	54.9	61.9	66.6	64.8	70.9	67.2

1942	40	6	3	31	80.1	62.6	66.6	79.8	82.9	83.8	86.8	87.9	87.3
1943	39	2	7	30	51.2	36.9	33.1	51.5	65.3	65.0	64.9	70.1	73.5
1944	41	8	5	28	71.4	53.1	53.6	63.1	72.7	77.6	80.3	79.8	83.2
1945	43	24	1	18	79.9	53.2	48.7	71.9	77.4	75.5	81.0	79.8	(1)
1946	48	16	0	32	68.9	50.9	48.7	72.0	72.4	71.6	75.9	77.3	84.6
1947	45	5	1	39	69.6	42.3	45.1	67.6	76.4	76.2	78.8	80.3	85.0
1948	46	14	3	29	80.2	57.6	60.6	83.0	85.1	96.6	91.6	89.9	93.8
1949	46	14	1	31	69.3	52.3	46.9	66.7	74.7	71.8	65.2	72.2	74.1
1950	42	18	2	22	75.1	58.7	61.8	74.5	81.0	85.5	78.0	73.0	88.4
1951	36	2	5	29	48.7	26.1	25.4	44.2	61.6	70.5	61.1	68.0	77.5
1952	36	5	3	28	66.7	46.5	49.2	68.1	76.9	81.0	76.4	82.1	86 9
1953	40	29	0	11	77.0	58.4	60.7	69.2	85.8	82.5	86.2	86.9	85.3
1954	40	15	2	23	62.7	42.1	43.9	62.9	71.3	77.6	74.2	80.6	80.7
1955	44	12	4	28	53.2	35.2	34.6	48.3	54.5	59.5	60.7	69.2	70.3
1956	51	16	5	30	50.4	35.7	38.3	46.7	52.5	58.3	53.5	63.2	71.9
1957	48	16	0	32	55.7	30.2	29.8	57.6	59.9	62.5	57.6	69.7	76.5
1958	44	12	1	31	54.5	26.7	29.4	44.7	52.6	58.7	53.6	63.7	69.8
1959	49	8	10	31	37.5	23.6	21.5	38.0	39.7	38.7	39.4	49.9	55.3
1960	48	10	2	36	54.3	32.4	33.1	50.8	64.6	60.3	56.3	66.6	73.7
1961	43	15	1	27	68.8	50.1	47.0	66.4	67.5	68.2	71.4	74.3	83.4
1962	42	6	8	28	48.5	31.0	30.3	51.9	53.7	47.1	52.6	59.0	67.4
Total or average	1,249	287	95	[2] 867	64.7	48.9	50.1	62.6	68.0	69.5	69.7	74.0	77.2
Percentage of total or of check	------	23.0	7.6	69.4	100.0	75.6	77.4	96.8	105.1	107.4	107.7	116.5	121.5

[1] Wintok was not grown in all nurseries in 1937 or 1945. Data on the parent variety Hairy Culberson, which is somewhat less hardy than Wintok, were substituted for the missing data in computing averages. Hence, Wintok's average survival is believed to be about 0.5 percent lower than it would have been had no substitutions been necessary.

[2] For 7 varieties grown 36 years. Differential killing in 709 nurseries reported for Wintok and in 729 nurseries reported for Fulwin.

Survival by Years

It long has been believed that if 50 percent or more of the winter oats survive the winter, the grower has a reasonable chance to produce a crop, weather conditions being average to favorable; but if less than 50 percent of the winter oats survive, the grower might well plow up the oats and use the soil for another crop. Average annual survivals for the nine oats, based on their overall annual percentage of survival, are given in table 4.

The data indicate that if the average nursery results are considered as a whole, regardless of how widely scattered or numerous the tests were in any 1 year, the more hardy entries survived sufficiently well. An analysis of the data for overall averages of the winter hardiness of the nine varieties indicated that the data are reasonably accurate and reliable enough for use by crop scientists.

Survival in Winter Temperature Zones

The seven winter temperature zones in the United States outlined in figure 1 are based on the average winter (December–February) temperatures in each zone (*1*). As would be expected, winter temperatures are successively lower as one proceeds from the south, zone 1, northward to zone 7. The data from Canada are considered separately.

TABLE 4.—*Average annual survival of winter oat varieties, 1926–62*

Years seeded and variety	Survival		
	Above 66.7 percent	50–66.7 percent	Below 50 percent
	Years	*Years*	*Years*
26 years:[1]			
Wintok[2]	25	1	0
Fulwin	21	4	1
Winter Turf (check)	14	9	3
36 years:			
Hairy Culberson	21	13	2
Pentagon	23	9	4
Tech	22	11	3
Winter Turf (check)	20	11	5
Lee	17	11	8
Fulghum	8	9	19
Appler	7	14	15

[1] Data for 1936–62.
[2] Data on Hairy Culberson, the somewhat less hardy parent of Wintok, substituted for certain missing data on Wintok in 1937 and 1945.

The data on survival of winter oats from these winter temperature zones have been considered in two ways: (1) The average percentage of survival of the different varieties in each zone based only on nurseries in which differential killing was observed (table 5); and (2) the number of all nurseries grown in which a usable stand (or 50 percent or more) of each variety survived (table 6).

TABLE 5.—*Percentage of survival of oat varieties grown in Uniform Winter Oat Hardiness Nursery in which differential killing was observed in winter temperature (December–February) zones of the United States and in Canada, 1926–62*

Years seeded and variety	Survival of differential killing in temperature zones—							Average survival	Survival in Canada
	1	2	3	4	5	6	7		
	Above 50° F.	45°–50° F.	40°–45° F.	35°–40° F.	30°–35° F.	25°–30° F.	Below 25° F.		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
26 years: [1]									
Wintok [2]	92. 8	88. 8	88. 3	81. 8	73. 9	51. 4	20. 8	77. 1	83. 9
Fulwin	92. 8	82. 4	88. 3	79. 6	69. 6	42. 6	16. 6	73. 9	80. 4
Winter Turf (check)	91. 5	80. 8	81. 3	68. 6	54. 1	29. 7	12. 3	63. 3	81. 1
36 years:									
Hairy Culberson	90. 4	82. 8	84. 5	73. 6	60. 2	35. 2	12. 9	69. 6	81. 9
Pentagon	87. 9	82. 6	82. 1	73. 4	61. 7	36. 3	11. 2	69. 4	80. 4
Tech	90. 8	81. 4	81. 1	70. 8	61. 1	34. 1	13. 7	67. 9	80. 4
Winter Turf (check)	86. 8	78. 9	80. 5	68. 2	53. 2	29. 7	12. 3	64. 6	82. 1
Lee	91. 9	77. 8	76. 8	65. 4	53. 8	26. 2	5. 0	62. 4	81. 2
Fulghum	83. 4	72. 4	71. 3	53. 1	30. 9	9. 2	2. 4	49. 9	75. 7
Appler	85. 5	74. 8	68. 2	52. 2	29. 1	8. 0	. 6	48. 6	75. 4

[1] Data for 1936–62.
[2] Data on Hairy Culberson, the somewhat less hardy parent of Wintok, substituted for certain missing data on Wintok in 1937 and 1945.

TABLE 6.—*Nurseries reporting a usable stand (50 percent or more) of winter oats and nurseries reporting less than 50 percent in 7 winter temperature zones of the United States and in Canada, 1926–62*

Number of nurseries and variety	Stations reporting survival in zones—									
	1		2		3		4		5	
	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent
1,075 nurseries reporting:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Wintok [1]	56	0	52	2	261	9	277	49	166	55
Fulwin	56	0	51	3	258	12	276	50	155	66
Winter Turf (check)	56	0	50	4	250	20	249	77	124	97
1,249 nurseries reporting:										
Hairy Culberson	70	4	65	8	313	34	296	77	143	91
Pentagon	70	4	64	9	311	36	293	80	148	86
Tech	70	4	64	9	311	36	287	86	144	90
Winter Turf (check)	70	4	63	10	307	40	276	97	127	107
Lee	70	4	63	10	305	42	270	103	127	107
Fulghum	69	5	60	13	294	53	230	143	80	154
Appler	69	5	61	12	283	64	225	148	74	160

Number of nurseries and variety	Stations reporting survival in zones—				Canada			
	6		7		Eastern		Western	
	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent	50 percent or more	Less than 50 percent
1,075 nurseries reporting:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Wintok [1]	49	60	2	22	0	2	11	2
Fulwin	34	75	1	23	0	2	11	2
Winter Turf (check)	25	84	2	22	0	2	11	2
1,249 nurseries reporting:								
Hairy Culberson	31	78	1	23	0	2	11	2
Pentagon	31	78	0	24	0	2	11	2
Tech	27	82	1	23	0	2	11	2
Winter Turf (check)	25	84	2	22	0	2	11	2
Lee	21	88	0	24	0	2	11	2
Fulghum	3	106	0	24	0	2	11	2
Appler	6	103	0	24	0	2	10	3

[1] Data on Hairy Culberson, the somewhat less hardy parent of Wintok, substituted for certain missing data on Wintok in 1937 and 1945.

The data in tables 5 and 6 indicate that killing was not severe in zone 1. The least hardy oats were injured markedly in zones 2 and 3, but even moderately hardy oats survived reasonably well. Only the most hardy entries escaped severe injury in zone 4. Data indicate that in zone 5 less hardy oats do not warrant serious consideration, moderately hardy ones approach a 50:50 gamble, and only the most hardy offer a reasonable promise of a crop.

Data from zone 6 indicate that only Wintok has a 50:50 chance; and data from zone 7 indicate that even Wintok has little or no economic promise as a crop for agricultural areas in that temperature zone.

For purposes of this analysis, data from stations located in Canada have been included as from separate zones. Oats in the two nurseries in eastern Canada were completely killed; in the few tests in western Canada, survivals were about as high as in zone 2 in the United States. Winter oats, therefore, appear to be of little or no interest for eastern Canada but attractive as a crop in southwestern British Columbia.

Effect of Altitude on Survival

It long has been considered that altitude affects survival in winter oats and other cereal crops. To determine the extent of this influence, the approximate altitudes of the different stations were recorded and the data on survivals at the different altitudes in the same temperature zone were compared. Data were assembled on the basis of altitude only in temperature zones 3, 4, and 5. It is well known that altitudes in temperature zones 1 and 2 are low and that winterkilling is comparatively light everywhere.

The general altitude at all lower elevations in zone 3 has little or no appreciable influence on survival. However, at altitudes above 1,000 feet, winterkilling becomes more severe, especially in less hardy oats. The exact altitude at which winterkilling becomes severe is not clear because it varies from year to year. Snow cover in some years can reduce the extent of winterkilling at moderately high elevations.

In zone 4 the altitude of some stations is as high as 4,000 feet; increased killing above 1,000 feet was obvious.

Data from zone 5 revealed severe killing at all levels, even when the altitude was below 1,000 feet. Above 1,000 feet, killing usually increased, except when snow cover was present. The influence of snow cover appeared more evident in less hardy than in more hardy oats.

In zones 6 and 7 weather is so rigorous for oats that killing is usually severe or complete in all nurseries, regardless of any other factors involved.

Effect of Soil Type on Survival

Soil type has often been considered an important influence on survival of cereal crops, particularly since it influences the extent of heaving when alternate freezing and thawing takes place. To determine the extent of this influence, the soil types on all stations conducting nursery tests for 10 or more years were determined, or for about 80 percent of the 1,249 reports.

Several soil types were reported, but in this bulletin the main types reported are: (1) Sandy or sandy loam, including fine or very fine sandy loam; (2) silt loam, including a few minor variations in designation; (3) clay or clay loam, including one report of silty clay loam; and (4) Houston clay, sometimes called black wax soil. In this report Houston clay was separated from other clay soils.

No reports on clay soils were included from winter temperature zones 1, 5, and 6; and no reports on any soil types were included from zone 7.

In general the data were compared by winter temperature zones and from nurseries with comparable altitudes. Data on survival in nurseries in which differential killing was observed appear in table 7.

Effect of Available Winter Moisture on Survival

Winterkilling of small grains is much greater in the more droughty western plains than in the more humid eastern areas of the United States. It is believed that reduced moisture caused in part by desiccating winds is an important factor in bringing this about (*2*). In this study the effect of available winter moisture on winter survival of oats has been evaluated.

Data were compiled from certain stations in the east and the west in the same winter temperature zone, having comparable altitudes and similar types of soil (table 8). If any advantage in altitude has been given, it has been to the western, more droughty stations.

In zone 2 data from tests on Houston clay in the west were compared with data from tests on other clay-type soils in the east. The overall difference between these results in the west and in the east were much greater than on results on general clay-type soils in zone 3 and are omitted since the soils were not comparable in the east and west.

With these omitted, the difference in survival in the east and the west on clay, silt, and sand indicates the advantage for survival of winter oats in the 63 eastern nurseries over the 67 western (table 8).

Regardless of soil type, winterkilling averaged 13.185 percent more in the droughty west than in the humid east. The mean differences by soil type were as follows: Clay soils, 7.378 percent; silt, 13.967 percent; and sandy soils, 18.211 percent. Thus, if the difference on clay soils is used as a standard, then killing on silt soils was nearly 90 percent greater on western dry soils than on eastern moist soils, and killing on sandy soils was about 146 percent greater. This would seem to be a clear indication of the influence on winter survival of oats of the water-retaining or drought-resisting qualities of the clay soils as compared with silt or sandy soils.

A second conclusion was that the lack of moisture in the west did not injure varieties uniformly. The lack of moisture had less effect on the most hardy than on the least hardy oats; thus, drought resistance is a factor in determining overall hardiness in an oat.

It has already been shown (*4*, *10*, *11*) that heat resistance and winter hardiness were correlated in oats and possibly other cereals. It now appears clear that cold (winter) resistance, heat resistance, and winter drought resistance are all correlated.

TABLE 7.—*Comparison of survival of oat varieties grown on several soil types in the same winter (December–February) temperature zone in which killing of a differential nature was observed*

Variety	Zone 1		Zone 2			Zone 3				
	Sandy loam	Silt loam	Sandy loam	Houston clay	Clay loam	Sandy loam	Silt loam	Houston clay	Clay loam	Sandy clay
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wintok	90.9	96.6	96.4	88.5	97.4	92.0	87.6	90.7	88.4	87.7
Fulwin	91.7	96.3	95.5	78.4	98.3	92.8	89.3	89.8	88.7	87.3
Hairy Culberson	85.8	91.7	93.7	75.8	97.2	90.3	84.8	82.3	87.8	79.1
Pentagon	85.6	94.4	94.0	75.4	97.5	89.5	82.5	79.0	82.7	80.2
Tech	84.3	93.4	92.0	74.4	96.8	91.7	83.7	78.4	81.6	71.4
Winter Turf (check)	83.6	96.2	93.4	70.0	93.7	88.8	80.4	79.8	79.7	75.4
Lee	83.8	95.6	90.5	69.5	94.2	84.8	78.7	72.0	75.2	74.9
Fulghum	81.8	88.3	92.3	60.1	94.0	84.4	69.8	66.2	64.0	72.4
Appler	78.8	96.1	91.3	63.6	100.0	81.6	66.3	66.5	57.5	70.0

Variety	Zone 4					Zone 5		Zone 6	
	Sandy loam	Silt loam	Clay (all)	Clay (east)	Clay (west)	Sandy loam	Silt loam	Sandy loam	Silt loam
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wintok	78.9	81.8	75.7	80.0	67.7	65.3	77.8	53.5	43.4
Fulwin	76.9	84.2	72.4	78.1	61.7	62.6	74.2	52.0	33.2
Hairy Culberson	73.1	76.1	66.2	72.6	54.1	58.6	60.1	40.3	27.1
Pentagon	73.3	75.7	66.2	73.1	53.2	54.1	63.7	45.5	27.1
Tech	71.6	71.6	64.3	68.7	56.1	51.5	63.9	30.6	26.3
Winter Turf (check)	67.2	68.9	64.6	67.9	57.3	51.1	53.6	37.3	17.9
Lee	62.6	68.0	59.1	64.7	48.6	49.3	55.3	29.3	16.0
Fulghum	57.8	54.2	40.2	46.2	28.9	26.9	31.8	6.5	7.1
Appler	51.7	53.7	44.0	50.8	31.3	16.9	32.1	1.6	7.4

TABLE 8.—*Differences in survival of oat varieties in different winter moisture areas when the varieties and temperature zones are the same, soil types are similar, and altitudes comparable* [1]

Years seeded and variety	Survival for zone, soil type, altitude, and location							
	Zone 1 Sandy soil		Zone 3 Clay soil		Zone 4			
					Silt soil		Sandy loam	
	Tifton, Ga. 370 feet	College Station, Tex. 360 feet	Statesville, Miss. 926 feet	Denton, Tex. 620 feet	Knoxville, Tenn. 1,004 feet	Stillwater, Okla. 870 feet	Waynesville, N.C. 2,756 feet	Woodward, Okla. 1,893 feet
36 years:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Appler	94. 3	57. 3	66. 0	49. 6	50. 9	32. 5	45. 5	30. 2
Fulghum	94. 1	58. 2	69. 9	58. 4	55. 9	33. 5	39. 8	36. 9
Lee	94. 4	65. 4	84. 0	67. 0	71. 4	50. 9	72. 6	46. 3
Winter Turf (check)	94. 3	64. 1	85. 8	74. 0	70. 9	53. 7	73. 6	55. 5
Tech	92. 2	68. 9	82. 8	80. 5	70. 7	54. 2	78. 0	62. 3
Pentagon	94. 6	66. 8	86. 4	79. 3	75. 1	63. 8	79. 3	66. 7
Hairy Culberson	94. 5	73. 9	86. 6	88. 9	77. 8	59. 3	73. 3	64. 2
26 years:								
Winter Turf (check)	95. 0	93. 2	89. 6	76. 4	74. 6	63. 8	73. 6	51. 0
Fulwin	96. 8	91. 6	92. 8	91. 2	86. 8	86. 2	81. 0	69. 0
Wintok	95. 2	98. 7	92. 3	91. 3	83. 8	83. 5	82. 3	72. 1

[1] In every comparison the altitude is more favorable to the more droughty region.

These data also indicate the extent of influence of soil type in winter injury under droughty winter conditions. Logically, clay soils having smaller soil particles do not dry out so rapidly as silt or, especially, sandy soils. The relative injury under droughty conditions is striking. Study of data in table 8 will show that under droughty conditions killing on silt soils was 189 percent of that on clay and killing on sandy soils about 247 percent of that on clay.

It long has been considered that extensive root development favorably influences hardiness. No results of such a study on oats are available. If such differences exist, then an oat should survive exceptionally well with droughty conditions as compared with moist soil conditions.

The overall survival in 1,249 nurseries of Hairy Culberson, Pentagon, Tech, and Winter Turf was 69.7, 69.5, 68.0, and 64.7 percent, respectively. Tech's record, especially, and possibly that of Hairy Culberson on dry clay are of special interest. The small amount of increased injury of these varieties on dry over moist clay soil is striking. The data may indicate that these two varieties have better root systems than Pentagon or Winter Turf, which are approximately as hardy as Hairy Culberson and Tech, respectively, when results from all areas, temperature zones, altitudes, and soil types are averaged.

Effect of Soilborne Mosaic on Survival

Soilborne mosaic of oats, caused by the *Marmor terrestre* var. *typicum* and *M. terrestre* var. *oculatum*, is very injurious to growth in winter oats and may reduce winter survival. In table 9 the survival of oats at special stations where mosaic is known to exist in the soil was compared with survival at all other stations in the same winter temperature zone of Southeastern United States. Data were summarized separately from hardiness nurseries on stations in temperature zones 3 and 4. The data on mosaic infections have been published (*17*, *18*, *19*). These data were obtained primarily in zone 3 and largely from the same stations as those from which hardiness data included here were obtained.

The data obtained from temperature zone 3 in a general way indicate that mosaic does influence winter survival. The overall reduction is not very great in any case, but the general trend is evident. Varieties that have appeared most susceptible to mosaic tend to have more reduced stands. These data were *not* recorded in areas where positive infection was known to exist in all years of tests. In some years the nursery was probably grown on infected soil whereas in other years the soil was not infected. Thus, averaging the data for several years reduces the accuracy and the extent of any losses shown.

Data from temperature zone 4 differed greatly from those in zone 3. The reason for such a difference is not known. Since varieties appearing highly susceptible in specific disease nurseries often gave increased survival on infected soil in zone 4, two possible explanations are as follows: (1) Nurseries were grown some years on infected soils and other years on noninfected soils; the results from the noninfected soils tend in such an average to negate results from infected soils; or (2) strains or races of mosaic exist and a variety highly resistant or

TABLE 9.—*Comparative survival of winter oats at stations known to have mosaic-infected soil with survival at stations with noninfected soil in winter temperature zones 3 and 4 of Southeastern United States, 1936–39*

Variety	Mosaic reaction[1]	Zone 3				Zone 4			
		Survival at noninfected stations		Survival at mosaic-infected stations		Survival at noninfected stations		Survival at mosaic-infected stations	
		Average	Compared with check	Average	Compared with check	Average	Compared with check	Average	Compared with check
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wintok	+11.4	89.6	106.5	87.5	105.8	82.5	115.2	85.0	105.3
Fulwin	−0.3	86.6	103.0	89.8	108.6	82.0	114.4	85.5	105.9
Hairy Culberson	+25.4	84.7	106.0	80.9	103.6	76.2	109.0	87.6	108.6
Pentagon	+6.8	83.2	104.1	81.0	103.7	76.0	108.7	81.4	100.9
Tech	+68.5	82.6	103.4	74.0	94.7	72.2	103.3	82.2	101.9
Winter Turf (check)	+29.1	79.9	100.0	78.1	100.0	69.9	100.0	80.7	100.0
Lee	+18.7	77.7	97.2	77.3	99.0	68.9	98.6	77.2	95.7
Fulghum	+11.6	70.9	88.7	70.1	89.8	54.7	78.3	74.3	92.1
Appler	+12.9	68.2	85.3	67.1	85.9	54.4	77.8	68.7	85.1

[1] Arlington oats used as check in mosaic nurseries and given a 0 value. Hence, + indicates less tolerant and − more tolerant to mosaic than check.

susceptible to one mosaic strain may react in a reverse fashion to a second mosaic strain. There are so many strains among important diseases of oats it is not inconceivable this very common situation probably also exists in soilborne mosaic of oats.

The apparent drought resistance of the two varieties Hairy Culberson and Tech could conceivably be an indication of an increased survival resulting from the absence of mosaic on western stations as compared with eastern stations. Both varieties are highly susceptible to mosaic. In the west, damage and reduced stands would be absent or presumably so, whereas in the east it would be considerable. This would tend to explain why these oats survived comparatively better in the west than in the east. Hence, their increased drought resistance could be questioned.

SUMMARY

The Uniform Winter Oat Hardiness Nursery was conducted for 36 years, 1926–62. Nurseries were grown at 119 locations in 29 States and in 2 Canadian Provinces. A total of 342 entries were grown for 1 or more years and 1,249 reports were summarized. These reports indicated that killing of all entries was observed in 95 nurseries; no killing was observed in 287; and killing of a differential nature was observed in 867—in 7.6, 23.0, and 69.4 percent of the nurseries, respectively. Winter Turf, the check variety equaling 100 percent, had an average survival of 64.7 percent during the study; Appler, the least hardy variety, had an average survival of 48.9, or 75.6 percent of the check; and Wintok, the most hardy variety, had 77.2, or 121.5 percent of the check.

The nine varieties grown for 25 to 36 years, from least to most hardy, were Appler, Fulghum, Lee, Winter Turf, Tech, Pentagon, Hairy Culberson, Fulwin, and Wintok. These represent not only all of the different hardiness levels found in fall-sown oats now grown commercially but also all of the decidedly different morphologic types grown in North America. The histories of these nine oats reveal that all except Winter Turf trace directly or indirectly to the old Red Rustproof oats in America. Winter Turf was introduced from Europe.

Data on survival by years based on average survival of 50 percent or more or survival of less than 50 percent reveal that Wintok is the only oat whose survival was never below 50 percent in any year it was grown, Fulghum's survival was below 50 percent in 19 of the 36 years it was grown, and Appler's in 15 of the 36 years.

Seven winter (December–February) temperature zones, based on 5° F. intervals from above 50° in zone 1 to below 25° in zone 7 for average winter temperatures, were used in this study of oat hardiness data. Data reveal that not even the least hardy oats were killed in zone 1. Appler and Fulghum were reduced somewhat in zones 2 and 3, but more hardy oats survived reasonably well. Only the more hardy escaped severe injury in zones 4 and 5; whereas even the most hardy varieties in zones 6 and 7 were killed.

Data were obtained on the effect of altitude on survival. In general, altitude appears to have little influence in any area below the 1,000-foot level. Above 1,000 feet, survival of less hardy oats is reduced. This is especially true at altitudes above 2,000 feet. At higher alti-

tudes in some mountain areas in Virginia and adjacent States, snow cover can apparently moderate the temperature and killing is less severe than at the same altitude farther south.

Winterkilling is slight in zones 1 and 2 regardless of soil type, but survival was better on the silt than on sandy soils. Possibly in the case of a sudden thrust of cold into these southern zones, silt soil tends to cool less rapidly than sand and killing is reduced thereby. In zone 3 no wide differences were observed; however, killing of less hardy oats was much less severe on sand than on clay. Possibly clay soils tended to heave more. In zones 4 and, especially, 5 average survival on silt soils exceeded that on other soil types.

Available winter moisture supply is widely recognized as an important influence on survival of winter cereals. A comparison was made between survival at stations in the more moist eastern areas and at stations in more droughty western areas. The differences were very marked, regardless of soil type and altitude. Reduction in moisture supply usually resulted in reduction in survival. In some comparisons the differences exceeded 20 percent, even though soil types and altitudes were comparable. Winterkilling averaged 13.185 percent more in the droughty west than in the humid east. Data indicated that the water-retaining or drought-resisting qualities of clay soils were superior to those of silt or sandy soils.

Soil organisms often tend to reduce surviving stands in winter cereals. The extent of the influence of soilborne mosaic in oats was studied. Not all nurseries at any station were sown on infected soil in all years, but the percentage of reduced stands were in general proportional to the degree of susceptibility of the oats to soilborne mosaic. In some cases reductions in most susceptible oats were sufficient to result in destroying the crop for practical purposes.

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U.S. GOVERNMENT PRINTING OFFICE: 1965 O—776-210