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OAT VARIETY STUDIES IN TENNESSEE

By

N. I. HANCOCK AND O. H. LONG



A recent winter-hardy selection from the cross Tenn. 090 x Bond.
It is early-maturing and resistant to rust.

KNOXVILLE

S U M M A R Y

1. Fall-sown oats are of considerably more value than spring-sown oats in Tennessee, the average of selected winter-hardy varieties yielding 31 bushels per acre more than the best spring varieties.

2. Fall-sown oats mature from a week to ten days earlier than spring-sown oats.

3. Fall-sown oats retard erosion during winter months when rainfall is heavy, and, when sown early, provide very palatable winter pasture.

4. As a rule, fall-sown oats mature before rust infection damages them seriously.

5. Winter-hardiness of a variety is its ability to retain dormant, prostrate seedling growth under varying climatic conditions and is of major importance in varietal improvement.

6. The Tennessee introductions, Tennex, Fulwin, and Forkedeer, possess this winter-hardiness character. They are often seeded after corn, with satisfactory results.

7. These Tennessee introductions, in all trials, proved superior in yield to Winter Turf, at one time the standard winter variety.

8. Semi-winter-hardy varieties do not retain dormant, prostrate seedling growth under variable climatic conditions.

9. In Tennessee, semi-winter-hardy varieties are adapted only to restricted dates of seeding in the fall.

10. Varieties such as Lee, Letoria, Stanton, and Fulgrain belong in the semi-winter-hardy group.

11. Low levels of fertility of oat land predominate in Tennessee and require vigorous varieties, such as Tennex, Fulwin, and Forkedeer.

12. On medium to high levels of fertility, Tennex, Fulwin, and Forkedeer have wide spread of seeding dates. Of these three, Forkedeer stands up best.

13. Semi-winter-hardy varieties thus far introduced are not vigorous growers and are better adapted to high levels of fertility than to low levels. Of this group, Fulgrain stands up best.

14. All three Tennessee varieties mature earlier than Winter Turf and Lee.

15. Fulgrain and the Tennessee selection of 090 x Bond 140-17-63-75 are the earliest-maturing of all oat varieties tested thus far, but they are sometimes damaged by late spring freezes.

16. For spring sowing, oat varieties having spring erect type of seedling growth are better than the winter varieties.

17. Oat varieties do not cross-pollinate as corn and rye do. Therefore, isolation of an oat variety is not necessary in order to get pure seed.

18. Appearance of seed is not a safe standard for selection of seed oats. Choose home-grown oats of proved, adapted varieties even though the seed may be somewhat discolored.

19. Variety identification from seed samples is of doubtful value. Field observation is the trustworthy method.

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INTRODUCTION

The small grains have become of increasing importance to farmers in Tennessee within the past few years. The acreage increased from 574,000 in 1929 to 1,065,000 in 1945.¹

Oats were harvested from only 30,000 acres in 1929, whereas, in 1945 the acreage is 181,000. During this period, production per acre increased from 15 bushels to 23 bushels, a gain of over 50 per cent.

These gains in acreage and production are due to a number of factors. Probably the most significant of these factors are: (1) the increasing use of the combine, (2) the necessity for selecting crops that require less labor, (3) the demand for more grain and pasture to meet the increase in livestock and dairy production, (4) the more widespread practice of seeding winter cover crops to check soil erosion, and (5) the introduction and distribution of improved varieties. It is the purpose of this bulletin to discuss this last factor as related to the oat crop.

TYPES OF PLANT GROWTH IN OATS

The utility of the oat plant and its wide adaptation are well known. Two types of seedling growth are commonly recognized: the winter (or dormant, prostrate) and the spring (or erect). The authors wish to add a third type, the semi-winter (or semi-dormant).

In northern and northwestern states, such as Minnesota, Wisconsin, Iowa, and Illinois, spring types are grown from seedings in the spring. This is true likewise in Tennessee, Kentucky, Virginia, and other states of approximately the same latitude. In the general latitude of Florida and Louisiana and the southern half of Mississippi and Georgia, spring types are grown from seedings in the fall.

The winter types from seedings in the fall are found in Tennessee, Kentucky, Virginia, Arkansas, Maryland, West Virginia, and southern Indiana. Semi-winter types may be grown in some of these states from seedings made early in the fall.

The semi-winter types from seedings in the fall are grown, for the most part, in Texas and the northern half of Mississippi, Alabama, Georgia, South Carolina, and North Carolina. There are small mountainous areas in some of these states where the winter types are sown to advantage, or where the semi-winter types must be seeded early if the plants are to survive.

¹Statistics from U. S. Crops and Markets.

It is apparent that the spring types constitute the largest acreage. In Tennessee, for many years the oat acreage has been seeded primarily to the spring type. As far back as 1890, Plumb (22) stated that spring rustproof types were best adapted to this State. In 1926, Mooers (14) stated that winter oats constituted only from 10 to 25 percent of the total oat crop.

In 1915, Mooers (13) stated that Grey Turf, or Winter Turf, was the standard winter oat in Tennessee. In 1926, Mooers (14) named Winter Turf and Culberson as the best winter-type varieties, but considered them as not especially high yielding. He showed, nevertheless, that they gave higher yields than the spring types.

Periodic failures occurred in severe winters with the widely distributed Winter Turf, and seeding dates in the fall were too restricted. Moreover, the new introductions, Fulwin, Tennex, and Forkeddeer, are considerably earlier-maturing than Winter Turf or spring types, and survive the winters when sown at widely separated dates. Improved introductions of semi-winter-hardy types with restricted seeding dates have given better results than the spring types, so that in 1945 the crops and markets statistician gives 50 to 65 percent of the oat acreage in Tennessee as now seeded to winter and semi-winter types—a considerable increase over the 10 to 25 percent of 1926.

In fact, there is little justification now for spring seedings of spring-type oats in Tennessee. They offer no pasture when pasture is most needed, and no soil cover when the high winter rainfall is depleting the soils. The seeding dates in the spring are very restricted; it is shown that only seedings in late February and early March can survive the high temperatures of late May and June which cause premature heading.

PLANT CHARACTERS OF OATS FOR TENNESSEE

Winter-Hardiness.—As indicated in the preceding discussion, winter-hardiness is the character of first importance in oats for Tennessee. A winter-hardy variety not only lessens the possibility of failure in a severe winter, but, what is of more significance, it offers a wide spread of seeding dates in the fall. Scarth et al. (25) have advanced many theories concerning the ability of the plant cells to withstand low temperatures. The resistance to formation of ice in cells and the dehydration effect of ice bring in the importance of osmotic pressure and permeability of the cell structures. A more practical approach is found in the experiments of Laude (9). He suggested that the relative winter-hardiness might be measured to advantage in the transition from dormant to active stage of growth.

He transferred pots of dormant plants of all small grains from field to greenhouse, where they were subjected to high temperatures and acquired an active, erect growth. Then they were placed in cold chambers and killing effects were measured. The experiment showed that killing varied with the amount of active spring growth

acquired under the variable periods of time the plants were exposed to high temperatures. This experiment is applicable to field conditions in Tennessee, where exceedingly variable temperatures are encountered during winter months. Frequently, a warm spell in December or February will cause semi-winter-hardy varieties to develop a spring habit of growth and to be killed by the cold spells which follow. Thus, the most important criterion for judging the winter-hardy character of oats is the ability of the variety to retain its dormant seedling growth under variable winter temperatures. The Tennessee winter-hardy varieties were selected under such conditions. In figure 1, the selection at the left has changed to spring, or erect, seedling growth, whereas the selection at the right retains dormant, prostrate growth.



Fig. 1—Spring-type seedling growth (left) compared with dormant, winter-hardy type.

Table 1—*Winter-hardiness index of some varieties included in cold-chamber tests at Iowa State College, Ames.*

Data taken from tables 4 and 5 of article by Murphy (17) in *Phytopathology* 29, 1939.

From table 4		From table 5	
Variety	Average hardiness index	Variety	Average hardiness index
Culberson	66.6	Tennessee 090	74.7
Fulghum 699-2011	62.5	Fulwin (Tenn. 1945)	69.2
Winter Turf	57.2	Forkeddeer (Tenn. 092)	50.0
Lee	51.0	Tennex (Tenn. 1884)	64.7
Appler	45.0	Winter Turf	55.0
Fulghum	39.6	Culberson	57.6
Ferguson No. 922	35.6	Fulghum 699-2011	51.7
Bond	21.4	Lee	31.9
Alber	19.1	Ferguson No. 922	30.1
Victoria	10.4	Alber	11.1

Many workers have measured winter-hardiness by means of cold-chamber tests; that is, by subjecting the plants in seedling stage to low temperatures. In this respect, the experiments of Murphy (17) are interesting because they contain the Tennessee selections 1945, 1884, and 092, which are known now as Fulwin, Tennex, and Forkedeer. Murphy was interested primarily in the effect of crown and stem rusts upon the winter-hardiness of the variety, and the data in table 1 show the average over-all results from infection and no-infection of the plants. It is evident from this table that Culberson, Fulghum 699-2011, and Winter Turf are most winter-hardy under the experimental conditions of his table 4; but under the experimental conditions of his table 5, in which the Tennessee selections were included, three of these ranked from 8 to 18 percent above Culberson and Winter Turf and 13 to 23 percent above their parent, Fulghum 699-2011.

Cold-chamber tests, though they can be correlated with tests made under field conditions, cannot simulate the many variable factors encountered in the field. For that reason, Coffman et al. (1) initiated uniform field tests in the different states. In table 2, results are given on those tests which contain the Tennessee winter-

Table 2—*Survival of Tennessee winter oats compared with other varieties in tests conducted by the U. S. Division of Cereal Crops and Diseases, in different states.*

Variety	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	Average
	Percent ¹	Percent	Percent	Percent	Percent	Percent	Percent
Winter Turf	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Fulwin	102.6	103.2	121.2	107.8	136.9	111.8	113.9
Tennex	103.9	101.8	117.8	.....	.....	.....	107.8
Forkedeer .....	.....	.....	.....	.....	.....	103.6	.....
Hairy Culberson	96.6	104.3	110.8	106.1	126.8	112.5	109.5
Lee	95.6	97.2	93.8	99.7	95.5	88.4	95.0
Latoria .....	.....	.....	112.0	94.8	104.7	96.4	101.9
Stanton .....	.....	.....	.....	88.1	94.5	83.3	88.6
Victorgrain .....	.....	.....	98.3	86.1	75.0	74.6	83.5
Fulgrain .....	.....	93.9	97.6	.....	83.4	73.7	87.2
Fultex .....	.....	101.0	89.1	78.3	77.6	.....	86.5
Appler	88.0	82.4	91.8	82.6	72.1	74.4	81.9

¹All percentages are calculated. See explanation in text.

hardy varieties. Winter Turf is used as a standard of comparison. All three Tennessee varieties show a higher plant survival than Winter Turf. Latoria is the only one of the recent rust-resistant introductions to excel Winter Turf two years out of four. Fulwin consistently surpassed Winter Turf.

These new rust-resistant varieties do not contain many genes for winter-hardiness. Latoria, Lelina, Stanton, and De Soto all are selections of Lee x Victoria (Stanton, 32). Lee itself is a selection from a cross of Winter Turf x Aurora; Fulgrain is a selection from a cross of Coker Norton 20-93 x Navarro; and Victorgrain is a selection from a cross of Fulgrain x Victoria (Stanton, 28). Fultex, grown and originated in Texas, is a selection from the cross of Nortex x Victoria (Murphy, 18). Aurora, Navarro, and Victoria all are spring types; while Winter Turf, Norton, and Nortex are inferior in winter-hardiness to all the Tennessee varieties. Hence, in table 3, these rust-resistant varieties are placed in the semi-winter-

hardy class. The class of spring types contains such varieties as Columbia and Kanota (Fulghum selections), Ferguson 944, and Burt, and should be seeded only in the spring.

Table 3—*Classification of some oat varieties as to winter-hardiness character.*

Winter Turf is the standard of comparison.

Winter-hardy group	Semi-winter-hardy group	Spring group
Fulwin Tennex Forkeddeer Culberson Wintok Fulghum 699-2011 Bicknell	Lee Letoria De Soto Lega Stanton Fulgrain Fultex Victorgrain	Columbia Kanota Ferguson 944 Appler Hastings (Hundred Bushel) Vieland Brunker Carolina Red Bond Victoria Richland

The importance of genes that provide the winter-hardy character in oats is readily apparent. But there are other factors, such as the physical conditions of the soil—its tendency to heave with freezing and thawing, and the levels of its fertility—over which the oat plant exercises no control. These factors are associated closely with winter survival, and are best controlled by early planting. Also on soils of low fertility early seeding must be practiced for winter survival, but on fertile soil, winter-hardy varieties will survive under wide spread of seeding dates.

The increasing use of oats for pasture brings into prominence the relative resistance of the leaves to top killing by heavy frosts and freezes. Many varieties recover from this type of winter injury, but the loss of green herbage for pasture should be taken into account. Tennex and Fulwin have dark-green leaves, which are not easily damaged. Among the semi-winter-hardy varieties, Stanton has medium-green leaves, whereas Fulgrain and Victorgrain have light-green leaves, which are injured by moderate freezing.

It is well known that snow coverage raises the temperature over seedling plants; a difference of as much as 10° to 15° F. has been observed. Under field conditions of this kind, spring types of growth have survived low temperatures. Weather records in Tennessee, however, do not justify dependence on snow cover as protection for varieties of poor winter-hardiness.

In the final analysis, the importance of winter-hardiness in oat varieties may be measured from actual yields of late seedings. In table 4, it is shown that late seedings of the winter-hardy group—Forkeddeer, Fulwin, and Tennex—yield from 10 to 12 bushels more than the semi-winter-hardy group—Lee, Fulgrain, and others—at both Knoxville and Columbia. Early seedings of the winter-hardy group are superior in yield by 6 to 8 bushels.

Lodging.—The wide use of the combine for harvesting emphasizes the importance of lodging. The oat plant must stand up in the field until its grain is fully ripened. In Tennessee, however, most oat varieties mature from early to late June, as may be seen



Fig. 2—Fulwin (left) infected by rust when seeded in spring, compared with Vicland, a resistant variety.

in table 6. Weather records show that during this period heavy rains may make it difficult to harvest grain at all. Besides, oats are commonly seeded on soils of low to medium levels of fertility, thus requiring vigorous types of plant growth, which have a tendency to lodge. While heavy applications of nitrates as a top-dressing in the spring increase the yield, they may cause lodging. Infection from such diseases as crown and stem rust, especially in the early stage of culm development, will cause lodging. Figure 2 illustrates heavy lodging of Fulwin infected by rust when seeded in the spring. Apparently, too, as grain becomes "dead ripe" the culms are more easily broken over in the yellow-straw stage than when they are in the green stage.

Table 4—The winter-hardy group—Forkeddeer, Fulwin, and Tennex—compared in yield with the semi-winter-hardy group—Lee, Winter Turf, and Fulgrain—at Knoxville and Columbia, for the three-year period 1939-1941.

Group	Knoxville		Columbia	
	Early seeding 18 Reps. ¹	Late seeding 18 Reps.	Early seeding 12 Reps.	Late seeding 14 Reps.
	Bushels	Bushels	Bushels	Bushels
Winter-hardy Forkeddeer Fulwin Tennex	72.9	61.3	47.3	65.1
Semi-winter-hardy Lee Winter Turf Fulgrain	66.8	49.5	39.6	54.4
Difference in favor of winter-hardy group	6.1	11.8	7.7	10.7

¹Replications.

Very few varieties resist lodging when several of these factors combine, as they did in 1945. Of the three Tennessee varieties, Forkeddeer stands up better than either Fulwin or Tennex. Fulgrain ranks above the medium-dwarfing varieties, such as Lee, Letoria, and Fultex. It will be recalled that one of the parents of Fulgrain is Navarro, a variety having very stiff straw. Among the more vigorous-growing varieties, Forkeddeer and Stanton rank above Winter Turf and Wintok. Of the spring types, Vicland appears to stand up better than Columbia, Kanota, and other Fulghum varieties. Of the rust-resistant varieties now being used as parents in crossing material, Bond is superior to either Victoria or Richland.

No satisfactory method is known for measuring the lodging character efficiently. The varieties must be observed in the field, where they are under stress from storms and rainfall. Lodging is much affected also by the plant-food supplies of the soil.

Disease Resistance.—Within recent years, good progress has been made in the selection and the distribution of disease-resistant oat varieties. It is wise to incorporate disease-resistant genes in the variety so long as other desirable agronomic characters are not lost in the process.

The diseases most common to oats are the two kinds of smut and of rust. Reed et al. (23) have listed 29 physiologic races of the loose smut, *Ustilago avenae*, and 14 physiologic races of the covered smut, *U. levis*. Murphy et al. (16) have listed 51 physiologic races of crown rust, *Puccinia coronata avenae*, and 21 physiologic races of stem rust, *P. graminis avenae*. The infections of both smut and rust are borne through the air, with only this difference, that smuts are carried on the seed while rusts are carried on growing plants.

The physiologic races of the two smuts, as shown by Sherbakoff (26), are easily controlled by dusting of the planting seed with New Improved Ceresan, and the method is not expensive. Varieties highly resistant to smut are at hand, however (table 5), and development of resistant varieties of agronomic value is progressing.

Table 5—Oat varieties highly resistant to smut and rusts.

Taken from Murphy et al. (18).

Resistant to smut	Resistant to crown rust	Resistant to stem rust
Victoria	Bond	Richland
Markton	Victoria	Iogold
Navarro	Rainbow	Rainbow
Bond	Alber	White Tartar
Black Mesdag	Capa	Jostrain

Thus far, the physiologic races of the two rusts cannot be controlled satisfactorily by dusting or spraying, so that crossing with varieties known to have high resistance to rust must be resorted to.

Murphy, Stanton, and Coffman (18) found the varieties listed in table 5 to be highly resistant to most races of rust. Unfortunately, these varieties all are of spring types and will not survive even mild winters in Tennessee. Besides, they do not possess all the

agronomic characters essential for this State. They have been crossed, therefore, with desirable native varieties and released under the names Letoria, Fulgrain Strain 6, Stanton, and Fultex. It has been shown that these new varieties do not possess the high degree of winter-hardiness necessary to survive winters in Tennessee, unless seeded early on soils of high levels of fertility.

Continued release may be expected of many selections having as parents some of the varieties listed in table 5. During the past year the Traveler, originated in Arkansas, was placed in production. This variety is from the cross of Victoria x Custis. Custis is a selection from the cross of Winter Turf x Aurora, and therefore has the same parents as the semi-winter-hardy variety.

Spring-type disease-resistant varieties have been relatively simple to develop from crosses with the highly resistant ones listed in table 5. These new spring-type varieties, of course, should always be seeded in the spring in this State. Vicland, from Wisconsin, holds much promise for spring planting in Tennessee. A number of these new spring-type varieties, however, such as Boone, Marion, Ranger, and Rustler, have been bred under climatic conditions of the West and Northwest and are not adapted to this State.

It should be kept in mind that Tennessee lies on the northern border of the Cotton Belt, and that low temperatures occur until late May. Hence, an infection of rust spores does not gain great headway before that time, as shown by Rosen et al. (24). But fall-sown, or winter, oat varieties usually are in the blooming stage, or the seeds are in the dough stage, by the middle of May, and the crop is ready for harvest by early to middle June (table 6). Consequently, for the past 18 years no serious damage from rusts was observed on winter varieties until the spring of 1945. March temperatures that year were the highest on record for Tennessee, so that rust infection did get an early start and caused lodging and loss of grain. Even so, Forkedeer, a susceptible variety, surpassed the disease-resistant varieties in average yield for the State. In most years spring varieties do not mature in time to escape rusts, so that rust-resistant spring varieties are an important consideration in Tennessee.

Winter-type varieties have been seeded in the spring, but their dormant seedling growth permits rust spores to spread rapidly. In the spring of 1945, rust damage to these varieties was so heavy as to cause almost complete failure (Fig. 2). On this account, a risk is taken when winter-type varieties are seeded in the spring. Sometimes crown rusts have infected early seedlings of oats in the fall. These seedlings usually are completed by the middle of September for pasture in November and the winter months. Ordinarily, the temperatures are high in September, but the rainfall is low, so that serious damage from rust is rare. On the other hand, from time to time, lice infestations have done great harm.

In addition to the smuts and rusts, there are minor diseases, such as blight, *Pythium* root necrosis, and *Helminthosporium avenae*. Various degrees of blasting are observed on spikelets of the oat panicle

almost every season. Derick et al. (3) and other workers have concluded that blasting is due to physiological conditions, such as moisture, light, and nutrition of the plant. Some varieties are able to adapt themselves to these varying conditions. *Helminthosporium* has been observed recently on early seedlings of oats and is sometimes mistaken for crown rust. Thus far no varieties of oats are known to be very resistant to this disease.

Table 6—Average dates of maturity of varieties when sown in the fall and in the spring, at three stations, Knoxville, Columbia, and Jackson.

Variety	Fall Seeding				
	Knoxville		Columbia		Jackson
	Early Sept. 22	Late Oct. 25	Early Sept. 18	Late Oct. 19	Early Oct. 13
	Maturity June 11	Maturity June 13	Maturity June 6	Maturity June 10	Maturity June 6
Tennex	" 11	" 13	" 6	" 10	" 8
Fulwin	" 12	" 13	" 6	" 10	" 8
Forkeddeer	" 15	" 16	" 9	" 14	" 12
Lee	" 18	" 19	" 12	" 15	" 15
Winter Turf	" 4	" 10	" 4	" 8	" 2
Fulgrain			" 3	" 8	" 5
Kanota			" 6	" 9	" 8
Victorgrain				" 9	" 8
Stanton				" 9	" 8
Average	June 10	June 15	June 7	June 11	June 9

Variety	Spring Seeding			
	March 5		March 3	March 1
	Maturity June 22		Maturity June 12	Maturity June 17
Columbia	" 22		" 12	" 15
Kanota	" 22		" 10	" 15
Brunker	" 22		" 12	
Trojan	" 22		" 12	
Fulghum	" 22		" 12	
Fulgrain			" 12	
Tennex	June 25		" 17	June 20
Fulwin	" 25		" 17	" 21
Forkeddeer	" 25		" 17	" 21
Average	June 23		June 14	June 18

Maturity.—While maturity does not rank in importance with winter-hardiness, lodging, and disease resistance, the cropping system of recent years demands that it be given consideration. A common practice is to seed lespedeza and red clover in small grains during February and March. Numerous trials show that alfalfa, soybeans, and sericea can be seeded in the same manner. An early-maturing variety will be harvested sooner than a late-maturing one, thereby resulting in less competition for water and nutrients between the grains and young legumes. When crimson clover is seeded with oats in the fall they should mature together if seed is to be saved. This calls for an early-maturing oat. But some seasons the variable warm spells through the winter will cause an early variety to come into bloom before danger of late freezes has passed. The tender flowers are frozen and fertilization is prevented, resulting in serious curtailment of yields.

In table 6 it is seen that the three Tennessee winter-hardy varieties mature considerably earlier than Lee or Winter Turf. Figure 3 shows the relative difference in maturity between Fulwin and Winter Turf. The Tennessee varieties are as early as Stanton,



Fig. 3—Fulwin (left) in full panicle, showing it to be considerably earlier than Winter Turf (right).

but later than Fulgrain. Seedlings of mid-September matured only 3 or 4 days earlier than those of mid-October. The maturity of the spring seedlings is considerably later than that of the fall seedlings. Spring seedlings, therefore, are not as desirable as fall seedlings for combination with legumes.

Plant Structure.—It should be understood that the stems, or culms, which bear the heads of oats come from underground roots. This habit of growth is called “tillering” or “stooling,” and is peculiar to all the grasses. The structures on the panicle bearing the grain are called “spikelets.” Love et al. (10) found a high correlation of yield with number of culms per plant, with number of spikelets per culm, and with height of culms at tillering. The Tennessee Station found a fairly high correlation, .684, of yield with grain weight per spikelet, and that size of grain compensated to some extent for loss in yield due to poor stooling.

Oat varieties differ considerably in structure and habit of growth. The three Tennessee winter-hardy varieties are prolific stoolers, Tennex being the most prolific. All have large, open panicles subtending many spikelets, Forkeddeer having the most compact panicle. Their grains are large, as shown by test weights of 34 to 38 pounds per bushel in most seasons. Tennex and Fulwin are tall and vigorous at time of tillering; Forkeddeer is of medium height. On soils of low to medium levels of fertility, their stems attain sufficient height for full development of panicles. In figure 4, the height and vigor of Fulwin are shown in contrast with those of Lee. Lee is semi-dwarf, a prolific stooler, with small compact

panicle and small grain; Letoria is similar to Lee in habit, with slightly larger grains; Fulgrain is semi-dwarfy, a semi-prolific stooler, with medium-compact panicle, and large grain; Bond is tall



Fig. 4—Vigorous plant growth of Fulwin (left) compared with semi-dwarfy growth of Lee.

and vigorous, a poor stooler, with medium-compact panicle, and medium-sized grains; Victoria is vigorous, a prolific stooler, with large, open panicles and large grains.

It is apparent that winter-hardiness, lodging, disease resistance, maturity, and plant structure all have a close association with yield, and that varieties differ in these characters. In the final analysis, however, the performance of a variety, in comparison with others under field conditions, is the only reliable criterion as to its merit.

YIELD TRIALS OF FALL- AND SPRING-SOWN OATS

Experimental Methods.—The yield trials (tables 7 to 16) were conducted at the Knoxville, Columbia, and Jackson Stations. They cover a period of 7 to 9 years.

The varieties are restricted to those which had shown some promise in new-strains tests at the main Station. In spite of this precaution, a variety may prove of no value. Promising introductions are entered from year to year. Hence, the data opposite each variety are not uniform for all years. In the case of Fulgrain, new, numbered strains have been released each year. Obviously, one year's comparison of each strain is not sufficient, so that the several strains are compared as a whole under the variety name. Only strain 6 is in the 1945 trials. The same varieties were in the

tests at all three stations every year with few exceptions. Lee is used as a standard of comparison for all fall seedings; Kanota and Columbia for spring seedings.

The plot size is one drill width of 8 rows 8 inches apart, and 60.5 feet long, or $1/130$ acre. Some years, two drill widths were used, or $1/65$ acre.

There are 4 to 6 replications of each variety at each station every year. The data in tables 7 to 14 give averages of these replications. The combined, or calculated, average of each variety is computed for the same years it is in trials with the check variety used as the standard of comparison. Straw yields are computed in the same manner. This method is in general use and is an attempt to give a comparison of varieties where the data are not uniform for all years. The method is not perfect by any means. For example, in table 7 Lee has higher yields than Stanton in 3 years out of 4; yet the abnormally high yield of Stanton in 1945 gives it the higher calculated average.

The yields of varieties in tests of this kind are not absolute. They are influenced by variations in soil fertility, by minor difference in stand, by losses during threshing, and other causes. These variations are averaged equally among the varieties, as nearly as possible. Beyond this, the degree to which the variations must be taken into account in drawing conclusions can only be estimated. One such estimate is termed the "least significant difference." Technically this means the size of the difference needed to indicate reasonable odds that the varietal differences are not due to these uncontrollable variations.

It is beyond the scope of this bulletin to explain the statistical estimates. They are figured by method of variance (Snedecor, 27), and are shown in the last line at the bottom of tables 7-11 and 13-15. They are considered only a supplement to efficient field technic in offering more information, and not as a criterion for measuring varietal performance. A variety is considered worthy when it has a consistently favorable standing, even though the difference may be smaller than a significant one representing any particular year. Thus, another fair measurement of varietal performance is obtained by tabulation of number of times it ranked among the first 3 or 4 in all tests where entrances were made. This tabulation is shown in tables 12 and 16.

Results from Fall-Sown Oats.—Tables 7, 8, and 9 represent early seedings of fall-sown oats. The yields at Jackson are higher than those at the other two stations, indicating that fall-sown oats are well adapted to West Tennessee conditions. The calculated averages of Forkeddeer are 14.0 bushels higher than those of Lee at Jackson, 8.8 bushels higher at Columbia, and only 2 bushels higher at Knoxville. Tennex and Fulwin are 3 to 13 bushels higher than Lee at Jackson and Columbia, but 1 to 3 bushels lower at Knoxville. All the semi-winter-hardy varieties except Stanton are lower in yield than Lee by 3.6 to 17.5 bushels at all three stations. Stanton is slightly higher than Lee at Knoxville.

Table 7—Average yields of fall-sown oats over a period of nine years, 1937-1945, at Knoxville Station.

Early seeding—average date, September 25.

Variety	Grain yields per acre by years									Average ¹	
	1937	1938	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Tennex	87.0	48.5	51.6	88.2	83.9	57.3	21.5	80.0	54.4	63.6	1.45
Fulwin	86.0	46.0	.....	82.0	74.5	57.4	22.0	78.9	58.1	61.6	1.47
Forkeddeer .....	.....	.....	61.9	88.7	75.8	60.2	18.6	79.0	75.3	64.8	1.46
Lee (check)	75.1	48.3	55.4	81.2	77.6	70.7	26.7	77.4	69.2	64.6	1.53
Winter Turf	54.8	36.1	44.8	70.2	62.5	.....	.....	.....	.....	51.4	1.58
Fulgrain	62.9	41.7	40.7	85.6	83.2	50.0	.....	79.1	68.0	59.5	1.14
Victorgrain .....	.....	.....	.....	.....	90.7	57.7	11.6	.....	.....	59.0	1.19
Stanton .....	.....	.....	.....	.....	.....	66.9	19.4	75.6	84.9	65.3	1.38
Kanota .....	.....	.....	.....	87.0	.....	.....	.....	.....	.....	.....	.....
090 x Bond .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
140-17-63-75-243 .....	.....	.....	.....	.....	.....	.....	.....	.....	73.1	.....	.....
090 x Victoria .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
139-13-102-248 .....	.....	.....	.....	.....	.....	.....	.....	.....	76.3	.....	.....
Average	73.2	44.1	50.6	83.3	78.3	60.0	20.0	78.3	69.9	.....	.....
L. sig. dif. ²	12.9	2.0	5.1	13.0	10.3	4.2	4.1	10.4	10.8	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.

Table 8—Average yields of fall-sown oats over a period of eight years, 1938-1945, at Columbia.

Early seeding—average date, September 18.

Variety	Grain yields per acre by years								Average ¹	
	1938	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Tennex	62.4	53.1	41.7	50.6	75.7	62.1	69.4	47.4	57.8	1.10
Fulwin	55.8	39.2	43.1	52.5	69.9	61.1	67.2	48.3	54.6	1.17
Forkeddeer .....	.....	51.8	45.4	50.2	74.6	59.4	66.9	57.4	60.3	1.21
Lee (check)	66.0	45.8	42.6	40.5	60.3	48.4	58.8	49.9	51.5	1.07
Winter Turf	28.8	37.9	35.1	30.2	57.5	45.7	.....	.....	39.9	1.14
Fulgrain	49.5	43.4	29.1	51.6	60.0	45.4	54.8	38.3	46.5	.92
Kanota	36.7	41.8	37.3	54.8	60.5	50.2	.....	.....	47.7	.99
Victorgrain .....	.....	.....	.....	.....	52.8	19.3	.....	.....	34.0	.66
Stanton .....	.....	.....	.....	.....	.....	.....	49.4	51.6	47.9	.88
090 x Bond .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
140-17-63-75-243 .....	.....	.....	.....	.....	.....	.....	.....	51.0	.....	.....
090 x Victoria .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
139-13-102-248 .....	.....	.....	.....	.....	.....	.....	.....	43.4	.....	.....
Average	49.9	44.7	39.2	47.2	63.9	49.0	61.1	48.4	.....	.....
L. sig. dif. ²	8.3	6.3	7.6	5.4	8.0	10.2	7.2	7.6	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.

Measured by significant difference, Forkeddeer yielded better than Lee in all 7 years at Jackson, 6 out of 7 years at Columbia, and 1 out of 7 years at Knoxville. Tennex and Fulwin had better yields than Lee in 5 out of 7 years at Jackson, 5 out of 8 years at Columbia, and 1 out of 9 years at Knoxville. Of the semi-winter-hardy varieties, Fulgrain yielded better than Lee 3 out of 7 years at Jackson, 1 out of 8 at Columbia, and not a single year at Knoxville. Stanton, a recent introduction, had better yields than Lee in 3 out of 4 years at Jackson, none out of 2 years at Columbia, and 1 out of 4 at Knoxville. Winter Turf is lower than Lee in calculated as well as actual yields at all three stations and has been dropped.

Late seedings of fall-sown oats at Knoxville and Columbia are shown in tables 10 and 11. With few exceptions, the same varieties are entered at the two stations. The data give adequate evidence

Table 9—Average yields of fall-sown oats over a period of eight years, 1938-1945, at West Tennessee Station, Jackson.

Early seeding—average date, October 14.

Variety	Grain yields per acre by years								Average ¹	
	1938	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Tennex	73.5	76.5	99.9	73.4	.....	102.8	95.1	88.9	84.4	2.08
Fulwin	68.3	78.8	100.8	77.9	.....	94.5	91.1	85.5	82.5	2.10
Forkedeer .....	.....	91.5	107.1	76.1	86.6	103.5	102.8	97.9	91.4	2.34
Lee (check)	55.5	80.3	92.7	³ 74.5	59.6	93.0	88.3	75.4	77.4	2.28
Winter Turf	38.3	76.5	88.2	.....	.....	.....	.....	.....	68.8	2.75
Fulgrain	51.8	88.5	68.8	71.6	80.4	.....	93.4	97.9	81.2	1.97
Kanota .....	.....	.....	67.5	73.4	.....	.....	.....	.....	65.2	1.63
Victorgrain .....	.....	.....	.....	74.3	87.8	75.0	.....	.....	80.8	1.87
Stanton .....	.....	.....	.....	.....	87.8	82.5	96.2	87.8	86.7	2.19
090 x Bond .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
140-17-63-75-243 .....	.....	.....	.....	.....	.....	.....	.....	74.3	.....	.....
090 x Victoria .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
139-13-102-248 .....	.....	.....	.....	.....	.....	.....	.....	90.0	.....	.....
Average	57.5	82.0	89.3	74.5	80.4	91.9	94.5	87.2	.....	.....
L. sig. dif. ²	7.6	7.4	8.2	8.8	6.9	10.2	7.6	9.0	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.³Estimated.

Table 10—Average yields of fall-sown oats over a period of five years, 1937-1941, at Knoxville Station.

Late seeding—average date, October 25.

Variety	Grain yields per acre by years					Average ¹	
	1937	1938	1939	1940	1941	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Tennex .....	.....	40.7	60.0	76.1	49.7	65.0	1.30
Fulwin .....	.....	38.3	54.0	72.9	45.5	60.4	1.28
Forkedeer	71.6	41.5	72.3	73.9	47.3	61.4	1.27
Lee (check)	73.8	11.4	47.3	67.4	44.1	48.8	1.17
Winter Turf	59.2	.....	36.7	56.4	25.3	37.3	1.19
Fulgrain	64.9	34.5	53.8	67.1	47.3	53.5	1.03
Victorgrain .....	.....	.....	.....	.....	54.7	.....	.....
Kanota .....	.....	.....	.....	69.9	.....	.....	.....
Average	67.4	33.3	54.0	69.1	44.8	.....	.....
L. sig. dif. ²	5.2	6.0	6.0	10.5	7.4	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.Table 11—Average yields of fall-sown oats over a period of five years, 1939-1944¹, at Columbia.

Late seeding—average date, October 19.

Variety	Grain yields per acre by years					Average ²	
	1939	1940	1941	1943	1944	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Tennex	48.4	70.2	78.3	35.0	67.9	60.0	1.08
Fulwin	48.4	66.0	76.9	32.9	74.5	59.7	1.09
Forkedeer	54.7	68.8	74.0	32.0	67.9	59.5	1.13
Lee (check)	52.1	60.5	74.5	27.1	55.1	53.9	1.00
Winter Turf	41.2	61.7	54.8	21.9	.....	45.2	1.05
Fulgrain	39.5	31.7	73.6	27.2	55.8	45.6	.80
Kanota	37.4	31.3	73.1	29.9	.....	43.2	.82
Victorgrain .....	.....	.....	75.9	6.7	.....	43.8	.71
Stanton .....	.....	.....	.....	17.1	51.1	44.7	.86
Average	46.0	55.7	72.6	25.5	62.1	.....	.....
L. sig. dif. ³	5.6	9.3	9.1	7.2	10.1	.....	.....

¹No late seeding made in 1942.²Calculated averages. See explanation in text.³Least significant difference. See explanation in text.

of the value of the winter-hardiness character in oat varieties. At the first of this discussion it was shown that the Tennessee winter-hardy varieties were not superior to Lee and other semi-winter-hardy varieties in early plantings at Knoxville. In table 10 it is seen that late seedings of all three Tennessee varieties—Tennex, Fulwin, and Forkeddeer—have calculated averages of 11 to 16 bushels better than Lee. Measured by significant difference, they were superior to Lee in 3 out of 4 years. Tennex and Forkeddeer had significant superiority over Fulgrain in 3 out of 4 years.

At Columbia (table 11) over a different period of time, and from earlier seeding dates, all three Tennessee varieties have a calculated average of 6 bushels better than Lee. With the exception of Fulwin, they were superior to Lee in 3 out of 5 years, as measured by significant differences. All of the semi-winter-hardy varieties have calculated averages from 8 to 10 bushels lower than Lee. None of them are significantly superior to Lee any year. It will be recalled that Winter Turf was considered the standard winter variety some years ago. In these late plantings, the Tennessee winter-hardy varieties are superior to Winter Turf in all tests at both stations.

Thus far, the capacity of the variety to yield in comparison with other varieties has been measured by calculated average and significant difference. A variety's ability to rank among the first three in actual average yield is further evidence of its adaptability. In table 12, Forkeddeer ranked among the first three 27 times out of

Table 12—*Number of times and percentage of times fall-sown varieties ranked among first three in yield of all winter tests.*

Variety	No. of times in test	Ranked among first three	
		No. of times	Percentage
Tennex	33	25	75.8
Fulwin	33	24	72.7
Forkeddeer	31	27	87.1
Lee	35	12	34.3
Winter Turf	32	0	.0
Fulgrain	33	6	18.2
Victorgrain	11	4	36.4
Stanton	12	6	50.0
Kanota	14	2	14.3

31 times it was in the tests, making the highest percentage, 87.1. Both Tennex and Fulwin, having averages of 75.8 and 72.7 percent, rank among the first three considerably more often than Lee or Fulgrain. This table shows the adaptation of Tennessee varieties to a wide spread of seeding dates in the fall, as well as to soil and other seasonal conditions. Winter Turf never ranked among the first three in the 32 times it was in tests.

Results from Spring Oats.—Results of the spring-oat trials are shown in tables 13, 14, and 15. At Knoxville (table 13), the differences in calculated averages of the spring-type varieties are too small to establish the superiority of any one variety. The Tennessee winter varieties seeded in these spring tests have a calculated average of 5 bushels lower than those of the spring-type varieties.

Table 13—*Average yields of spring-sown oats over a period of nine years, 1937-1945, at main Station, Knoxville.*

Spring seeding—average date, March 8.

Variety	Grain yields per acre by years									Average ¹	
	1937	1938	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Columbia	.....	.....	.....	73.2	34.4	30.3	27.7	20.1	20.5	31.7	.77
Kanota (check)	32.3	18.0	23.7	47.4	37.4	26.2	35.3	22.4	25.4	29.8	.62
Brunker	33.1	25.2	33.1	52.9	35.7	24.5	24.9	18.5	29.3	30.8	.61
Trojan	31.6	21.3	24.4	52.3	.....	.....	.....	.....	.....	32.4	.65
Fulghum	35.9	21.7	26.7	49.4	.....	.....	.....	.....	.....	33.4	.62
Tennex	.....	.....	.....	.....	.....	30.1	34.3	18.2	5.4	24.0	.63
Fulwin	.....	.....	.....	.....	.....	31.0	35.6	22.3	4.8	25.5	.65
Forkedeer	.....	.....	.....	.....	.....	32.5	33.1	22.7	5.0	25.4	.68
Vicland	.....	.....	.....	.....	.....	.....	.....	33.2	27.2	37.7	.75
Average	34.0	20.7	23.1	56.4	36.1	29.0	31.8	21.8	16.8	.....	.....
L. sig. dif. ²	5.5	1.7	3.9	4.8	2.9	3.8	5.9	4.5	3.5	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.

Further examination of the table, however, shows that abnormally low yields in 1945 pulled down the calculated average of these winter varieties because they excel the spring-type varieties in each of the other three years. Columbia, described by Neel (20), is superior to Kanota in 3 out of 5 years, but other varieties do not excel it when measured by significant differences. At the Columbia Station (table 14), the spring-type varieties have about the same calculated

Table 14—*Average yields of spring-sown oats over a period of nine years, 1937-1945, at Columbia.*

Spring seeding—average date, March 2.

Variety	Grain yields per acre by years									Average ¹	
	1937	1938	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Columbia (check)	59.6	51.2	54.3	26.3	15.6	39.4	29.9	41.3	49.0	40.7	.87
Kanota	55.3	38.0	40.3	.....	23.1	37.7	25.7	.....	53.6	37.3	.71
Brunker	36.7	41.2	43.2	.....	25.6	47.8	32.7	42.2	45.0	37.6	.79
Trojan	51.4	42.1	39.7	29.4	20.0	36.6	28.7	.....	.....	36.5	.76
Fulghum	54.6	48.6	42.9	20.0	28.8	36.6	29.9	30.3	.....	37.4	.70
Burt	53.7	43.1	40.7	20.3	.....	.....	.....	.....	.....	33.6	.79
Illinois Hulless	47.4	43.4	39.9	16.3	.....	.....	.....	.....	.....	31.3	.76
Fulgrain	43.0	47.0	43.9	26.3	21.3	31.9	28.4	.....	.....	35.6	.69
Tennex	.....	.....	.....	.....	.....	26.7	28.5	22.1	13.2	23.1	.55
Fulwin	.....	.....	.....	.....	.....	31.4	23.7	23.0	12.0	23.0	.65
Forkedeer	.....	.....	.....	.....	.....	35.6	28.2	25.8	15.0	26.7	.69
Vicland	.....	.....	.....	.....	.....	.....	.....	32.1	41.0	32.9	.74
Average	50.2	44.3	43.1	23.1	22.4	36.0	28.4	31.0	32.7	.....	.....
L. sig. dif. ²	5.7	7.6	5.5	9.9	7.2	12.3	8.5	5.5	3.0	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.

average; none of them are as high in yield as the check variety, Columbia; all of them have higher averages than the Tennessee winter varieties. When measured by significant differences, no one of the spring-type varieties is consistently better than another. At Jackson (table 15), Columbia, Brunker, and Vicland are superior in calculated average to Kanota. All four varieties are better than Tennessee winter-hardy types. When measured by significant differences, Columbia excels Kanota 3 years out of 6 and Brunker 3 years out of 5.

Table 15—Average yields of spring-sown oats over a period of seven years, 1939-1945, at Jackson.

Spring seeding—average date, March 6.

Variety	Grain yields per acre by years							Average ¹	
	1939	1940	1941	1942	1943	1944	1945	Grain	Straw
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons
Columbia .....	.....	31.5	42.8	39.0	52.5	48.0	62.5	45.5	1.05
Kanota (check)	39.4	30.0	36.5	29.3	57.0	55.5	51.8	42.8	.94
Brunker	51.8	.....	40.1	.....	53.3	53.3	68.6	47.6	.93
Trojan	48.4	22.5	.....	.....	.....	.....	.....	43.7	.92
Tennex .....	.....	.....	.....	35.3	48.0	42.0	14.6	30.9	.82
Fulwin .....	.....	.....	.....	33.8	52.5	41.3	13.0	31.1	.91
Forkeddeer .....	.....	.....	44.4	33.0	48.0	45.0	14.7	34.4	.92
Vicland .....	.....	.....	.....	.....	47.3	72.0	.....	47.6	1.03
Average	46.5	28.0	41.0	34.1	51.9	47.5	42.5	.....	.....
L. sig. dif. ² .....	.....	.....	4.6	7.4	4.8	9.6	5.1	.....	.....

¹Calculated averages. See explanation in text.²Least significant difference. See explanation in text.

Table 16—Number of times and percentage of times spring-sown varieties ranked among first two in yield of all spring tests.

Variety	No. of times in test	Ranked among first two	
		No. of times	Percentage
Columbia	21	11	52.4
Kanota	23	8	34.8
Brunker	22	14	63.6
Trojan	13	2	15.4
Fulghum	12	6	50.0
Tennex	12	1	8.3
Fulwin	12	2	16.7
Forkeddeer	12	3	25.0
Fulgrain	7	2	28.6
Burt	4	0	.0
Vicland	6	3	50.0

When rank of the variety is considered (table 16), Columbia, Brunker, Fulghum, and Vicland are leading spring-type varieties. Kanota is a good selection of Fulghum—and why it does not make as good a record as its parent is difficult to explain, unless the seed was low in varietal purity. The low yields of Tennessee winter varieties in 1945 are the result of heavy rust infection. The retention of the dormant, prostrate growth in the seedling stage gave ample opportunity for the rust to spread rapidly. It is sometimes hazardous to seed winter-type varieties in the spring. Further examination of the 1945 tests shows that Vicland, a rust-resistant variety, exceeded Columbia and Brunker, susceptible varieties, only at Jackson.

In the discussion of Types of Plant Growth in Oats, it was stated that the seeding of spring oats in Tennessee is not justified. In table 17, the actual averages of the winter varieties, Tennex and

Table 17—The winter-oat varieties, Fulwin and Tennex, compared in yield with the leading spring-oat varieties, at Knoxville, Columbia, and Jackson.

Knoxville Average for 9 years		Columbia Average for 7 years		Jackson Average for 5 years	
Fulwin and Tennex	Bushels 62.6	Fulwin and Tennex	Bushels 58.2	Fulwin and Tennex	Bushels 91.0
Brunker and Kanota	30.3	Brunker and Columbia	39.9	Columbia and Kanota	46.8
Difference in favor of winter oats	32.3	Difference in favor of winter oats	18.3	Difference in favor of winter oats	44.2

Fulwin, are compared with those of the spring varieties. The data were taken when the paired varieties were in the trials the same years. They show the definite superiority of fall-sown winter-hardy varieties over spring-sown varieties. Other varieties could be chosen, but the results would be very similar.

The average yields of fall-sown oats each year (tables 7, 8, and 9) exceeded the yields of spring-sown oats (tables 13, 14, and 15) every year at all stations, except in 1943 at Knoxville. This exception can be explained by the fact that the spring-oat test received nitrate, while the fall test received none. All the late seedings of fall-sown oats (tables 10 and 11) are superior in yield to the spring seedings, except in 1943 at Columbia. This exception can be explained by the low yields of Victorgrain and Stanton.

In some years there is a scarcity of hay, and the seeding of spring oats is resorted to for hay production only. Table 18 shows

Table 18—*Yields of hay from spring-sown oats, at Columbia.*

Dates seeded: 1942, March 10; 1943, February 20.

Variety	1942	1943	Average
	Tons	Tons	Tons
Columbia	1.76	.55	1.16
Burt	1.58	.64	1.11
Fulghum	1.07	.72	.90
Tennex	.66	.61	.64
Fulwin	.94	.66	.80
Forkeddeer	1.07	.60	.84
Average	1.18	.63	.91

that spring oats are a poor substitute for early cuttings of alfalfa. On account of their dormant growth, winter varieties sown in spring are not as high in yield as spring varieties. High yields of hay are obtained from the seeding of winter-oats and vetch in fall, and this practice is common.

Seeding Dates.—Optimum seeding dates for oats are given by Mooers (15), but in some years late harvesting of corn raises the question of later seeding of oats. Results from fall- and spring-sown oats at different seeding dates are shown in table 19. These

Table 19—*Average yields per acre of oats when sown at different dates in the fall over a period of six years, and in the spring over a period of five years, at Columbia.*

Fall-sown oats 1939-1944		Spring-sown oats 1927-1931	
Date of seeding	Yield	Date of seeding	Yield
	Bushels		Bushels
Aug. 16	38.5	Feb. 15-29	31.4
Sept. 1	39.6	March 1-15	27.3
Sept. 15	41.6	April 1-15	17.2
Oct. 1	41.4		
Oct. 15	41.3		
Nov. 1	31.1		
Nov. 15	29.3		
Dec. 1	20.0		

seedings were made on soil of medium fertility at Columbia, and, unfortunately, the Tennessee winter-hardy varieties were not included. The data show, however, that the yield from November 1

seeding of fall-sown oats is equivalent to that from early spring seeding, and that November 15 seeding is better than March seeding. December and April seedings of oats may be considered as not worth while. In Tennessee, average temperatures are around 70° F. in September, 60° F. in October, 48° F. in November, and 40° F. in December. McClelland (12) has given some interesting climatic data. Young seedling oat plants do not grow rapidly when temperatures fall below 50° F., so that optimum yields are not very probable from seedings later than October. Where seedings of winter-hardy varieties are made on soils of medium to high levels of fertility until the middle of November, yields as good as those from spring seedings can be expected. The fertility of the soil enables the young seedling plants to take advantage of warm spells during the winter. On high elevations, such as the Cumberland Plateau, and on soils of low levels of fertility, seedings of oats should be restricted to September.

Winter Oats for Pasture.—The value of small grains and crimson clover for winter pasture is well established. Hazlewood (7) shows that 151 days of pasture might be obtained from crimson clover. Oats furnish palatable grazing for poultry and other livestock. Parker et al. (21) state, "The Tennex winter oat seems to be especially well suited for poultry pasture." Sheep were observed to graze all oat plots—injuring them severely—before attempting to graze rye, wheat, and barley plots, which were in the same experiment. In field observations, other classes of livestock show preference for oats. It has been stated that seedling growth of Tennex, Fulwin, and Forkeddeer is dark green and is not top-killed by heavy frosts. These varieties, therefore, are well adapted to pasturing.

There is no doubt that the grazing of oats lowers grain yields. The value of the green herbage consumed, however, should offset the loss in grain. The value of the time period for grazing during winter months should be considered also.

Of the small grains, oats rank second to Balbo rye and barley in rapidity of seedling growth and acquirement of sod for pasture. Livestock should be grazing and firming this sod before the latter part of November, when freezing and thawing set in. Thus, the

Table 20—Average yields of fall-sown oats for 1945, at Plateau Station, Crossville, and at Highland Rim Station, Springfield.

Variety	Crossville	Springfield
	Bushels	Bushels
Tennex	49.9	58.0
Fulwin	50.4	55.7
Forkeddeer	50.6	63.1
Lee	54.2	50.3
Stanton Strain 2	40.5	65.2
Fulgrain Strain 6	38.2	60.6
090 x Bond 140-17-63-75-243	49.2	66.4
090 x Victoria 139-13-102-248	45.7	56.3
Average	46.2	56.5
L. sig. dif. ¹	5.1	5.5

¹Least significant difference. See explanation in text.

seeding dates for oats is an important consideration. In the preceding discussion, a wide range of seeding dates is offered where grain production is the primary object, and where winter-hardy varieties are selected. In the case of pasture, however, seeding dates are restricted to September, and possibly early October, on soils of high-fertility levels. Very little pasture can be expected on soils of low fertility.

The combination seeding of barley and crimson clover is often used for pasture. The strain Tenn. 090 x Bond, 140-17-63-75-243, has very early maturity and ripens at the same time as crimson clover. It has some promise, as shown by its yield in 1945 (tables 7, 8, 9, and 20).

BREEDING WINTER-HARDY OATS

The Tennessee Winter-Hardy Varieties.—Varieties from cultivated red oats, *Avena byzantina* C. Koch, as distinguished from wild red oats, *A. sterilis* L., have been grown in the South for a long time. Some years ago, J. A. Fulghum made a selection from Red Rust-proof oats at Warrenton, Georgia, resulting in the Fulghum variety mentioned by Stanton (30). It has been shown that Fulghum and Red Rustproof varieties such as Ferguson 71 are of spring-type growth. In 1926, however, Stanton (32) reported winter-hardy selections from Fulghum, and one, No. 699-2011, was among the best of these progenies. Seed of 699-2011 were sown at Knoxville, where many off-type plants were observed. Twenty-five hundred panicle, or head, selections were made and sown in head rows in the fall of 1930 and the fall of 1931. The Tennessee winter-hardy varieties—Tennex, Fulwin, and Forkedeer—are descendants of these selections from Fulghum, or the *A. byzantina* species.

Species of Oats.—Etheridge (4) does not include *A. byzantina* in his classification of 1916. It should be kept in mind, however, that since then, as shown by Coffman et al. (2), a great deal of new material has been introduced, and variations have been found in old varieties, such as Burt. Nevertheless, there are few species of interest to growers of oats. Lee, Winter Turf, Culberson, and most of the white oats belong to *A. sativa*. The wild oat, *A. fatua*, is important in many states, and fatuoids, or false wild oats, are often found in varieties derived from Fulghum.

These fatuoids are observed readily by the long, twisted, black awn on the lemma of each lower grain. These plants are not numerous, but should not be permitted to accumulate over a period of years. Of more importance than the morphological classification of species is the discovery that most varieties of agronomic value belong to species which have 21 chromosomes as their haploid complement. It follows that the varieties are compatible as to crossing, and, having three times the normal set of 7 chromosomes, they are polyploids and vigorous in plant growth. Victoria and Bond cross as readily with Fulghum selections, *A. byzantina*, as with Lee, *A. sativa* (Stanton, 33).

This fortunate circumstance has enabled the breeder to incorporate disease-resistant genes of Bond and Victoria in their native varieties.

Crossing and Selection.—The oat flower is difficult to pollinate. The reproductive parts are enclosed in three separate structures, the palea, the lemma, and the glumes. The male parts, or three stamens, dehisce pollen and bloom for a short time, from 2 to 4 o'clock in the afternoon of each day. Blooming begins when spikelets first show themselves in the sheath of the culm. Oat pollen is very sensitive to moisture—the cells burst in moist air. The cells do not withstand low temperatures, and very early-maturing varieties are injured by cold spells in the spring. Also Garber et al. (6) have shown that natural crossing of oats has seldom been observed. Oats are recognized as being self-fertilized, and the grower need not be concerned about isolation from his neighbor's variety, as in the case of corn or rye.

In winter-hardiness, Tennessee 090 ranked above all other varieties and selections (table 1)—a result corroborated by the field tests



Fig. 5—First generation of oat plants grown in greenhouse. Their vigor makes it necessary to stake and tie them.

of Coffman et al. (1). This selection is semi-dwarfy, however, and is not considered vigorous enough for Tennessee soils. Therefore, crosses were made of Tennessee 090 with Bond and Victoria, combining winter-hardiness with the vigor and disease resistance of these two varieties. Selections of these crosses are shown, in tables 7 to 9, for the 1945 test. Comparative yields are shown also in table 20, which contains the uniform tests at Crossville, on the Cumberland Plateau, and at Springfield, on the Highland Rim. The importance of winter-hardiness is seen in the Crossville test, where Forkeddeer, Fulwin, and Tennex gave yields superior to those of Stanton, Fulgrain, and Lee. The 090 x Bond 140-17-63-75-243 ranked well at both Crossville and Springfield.

The grower should realize that a long period of time must elapse before a variety can be selected and its performance assured. The method used at the Tennessee Experiment Station is as follows: Seeds from a cross are planted in small pots, one seed to each pot. Plants are transplanted 4 inches apart in rows 1 foot apart. These plants are grown in greenhouse and staked, as shown in figure 5. This results in a large population of heads, or panicles (Fig. 6). These panicles are threshed separately and each one is planted in a small row, called a head row (Fig. 7). The second-year head selections, or F_2 generations, are taken on these head rows and again each head is planted in a small row. After this time, if the selection is considered promising the heads of single rows are massed and planted in rod rows; then 2-row plots, 25 feet long, are planted; these are followed by 5 drill rows, 50 to 60 feet long, and finally by a uniform test of drill plots. Thus, 6 years are consumed even when the breeder is fortunate enough to succeed with the first selection. But he is not very often so fortunate, and it is more likely that 10 years will elapse before he can release a worthy strain.

Many oat characters segregate in the well-known Mendelian ratios. Some are completely dominant in the first generation, while others are intermediate, and succeeding generations segregate in 3:1, 1:2:1, 15:1, 64:1, and other ratios. The winter-hardiness character is not so simple in analysis, because prostrate growth versus erect growth must be considered along with the length of time the prostrate growth continues. Stiff versus

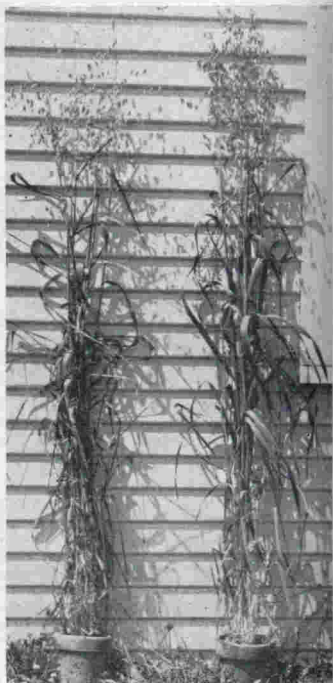


Fig. 6—Another view of entire plant from single-crossed seed, showing vigor and large number of panicles.

weak straw, many versus few culms per plant—all such characters are quantitative and complex. Experiments pertaining to them are in progress, but too much space would be required for their discussion here. Stanton (28) has given a general summary of ratios on inheritance of oat characters; Garber (5) and Hayes et al. (8) afford other sources of information.



Fig. 7—Head rows of oats in nursery. Each row planted from seed of single head, or panicle.

IDENTIFICATION AND ADAPTATION OF VARIETIES

Identification of Varieties.—Differences in morphological structure of the oat grain are employed as a means of identification of varieties. The oat grain is developed from the fertilized florets of the spiklet. There are one, two, or rarely three of these fertilized florets. The axis bearing the florets is called the rachilla and connects the spiklet with its supporting pedicel. When florets mature, they are known as first, or lower, and second, or upper, grains of the spikelet. When the lower grain separates from its pedicel, a distinct cavity, sometimes called suckermouth, is seen on the grain of Red Rustproof oats, but in Fulghum this scar is almost always absent. When the second grain separates from the first, a rachilla segment remains attached to the grain in Red Rustproof, but in Fulghum the segment remains attached to the rachilla. Many other differences might be mentioned.

These fine distinctions may be useful in separating variety groups, as pointed out by Stanton (29); but morphological structures of this kind are influenced too much by environment and by methods of combining and processing to be of value in distinguishing varieties of a group. For example, Kanota, a selection of Fulghum, has a spring, erect habit of growth for spring seeding; and Forkedeer, a selection of Fulghum, has a winter, prostrate habit of

growth for fall seeding. Yet the grains and segment attachments are almost identical. The same comparison can be made with reference to Forkeddeer and Fulwin, which are very different in field appearance and other growth habits.

Seed identification of varieties has come about through inadequacies of the Federal and many state seed laws. Varietal purity has been confused with mechanical purity. Federal and state seed analysts have properly assumed responsibility for mechanical purity, such as percentage of trash or inert matter, of germination or viability of seeds, of broken or badly processed seeds, of weed seeds, and other crop seeds. But when they assume responsibility for measuring varietal purity from a small sample of seed, their knowledge must be extended to cover not only the many varieties of oats, but also of other farm crops. No group of plant breeders who originated the varieties can be found to assume such wide knowledge.

The variety should be identified and its purity measured in the field where it has been planted with known sources of seed. The burden of meeting these requirements should fall upon the vendor. If he is unable to obtain the information, the variety should be labeled "unknown." This procedure is followed under the seed law of Indiana.

Adaptation of Varieties.—Every year, quantities of spring oats from spring-type varieties grown in western and northwestern states are distributed for fall seedings in Tennessee. Growers are attracted by their low price and bright appearance. Proof has been given that these spring-type varieties are not at all adapted for fall seedings in this State. In the future, new spring varieties will be released from this region carrying the additional attraction of disease resistance.

It has been shown that new winter-hardy strains containing disease resistance are being bred for Tennessee conditions and will be released shortly. Semi-winter-hardy varieties having disease resistance are available also and can be used for fall plantings, if seeded early on soils of medium to high fertility. Furthermore, resistance to diseases such as crown rust is not as important a consideration as winter-hardiness in fall-sown oats, because they mature before the infection is able to spread. On the other hand, rust resistance has been shown to be very important in spring-sown oats, so that some of the western spring varieties possessing disease resistance might be adaptable to spring seeding.

In most cases, however, they are not vigorous enough for this purpose. Tennessee soils, on an average, have not yet reached sufficiently high fertility levels to justify the substitution of dwarfy and semi-dwarfy varieties for vigorous-growing ones. Where livestock predominates, soil-fertility levels have become high, and less vigorous types of growth are adapted to these areas. On many livestock farms, pasturing of oats is the primary need—and the vigorous types recuperate in time for fair grain yields.

The increase of over 50 percent in average oat yield per acre might appear encouraging, but it represents an average of only 23 bushels per acre. This low yield is explained in part by the continued practice of seeding 35 to 45 percent of oat land in spring oats; it also shows, however, that most soils seeded to oats in Tennessee are of low fertility. Varieties attaining vigorous growth, or plant height, therefore, are necessary for reasonable yields on such soils. Luebke et al. (11) have shown intensive cropping of land with cotton and corn to result in depletion of soil fertility.

Varieties having the winter-hardy character are necessary for fall-sown oats on those areas of high elevation in the State, such as the Cumberland Plateau and the upper East Tennessee Valley. The average low temperatures and late spring freezes in these areas do not permit the substitution of semi-winter-hardy types.

The oat-production gains cited in the introduction are not restricted to Tennessee. Other states in the South have made notable progress. The distribution of hybrid material—of Bond from Australia, and of Victoria, Alber, and other varieties from South America—by the U. S. Division of Cereal Crops and Diseases, has given plant breeders of the state experiment stations an opportunity to make greater strides than ever before. Each breeder, of course, is interested in his particular environmental conditions. All states south of Tennessee are more concerned with resistance to rusts than with winter-hardiness, because these diseases spread infection early and cause severe damage to yields, whereas the winters are seldom cold enough to injure semi-winter-growth types. Thus, Fultex, Ranger, and Rustler have come from Texas; Camellia from Louisiana; Traveler from Arkansas; De Soto from Georgia; Quincy from Florida; Fulgrain, Victorgrain, and Stanton from South Carolina (Coker Pedigreed Seed Co.); and Letoria from North Carolina. No other crop has had so many new, improved introductions within the last 10 years.

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