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THE ATCHISON EXPERIMENT ORCHARD

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Tree 7I in the Atchison orchard, Variety Richared, straw mulch, seven years of age, and bearing its first crop. This tree was killed by the November freeze, 1940.

THE ATCHISON EXPERIMENT ORCHARD.[1]

R. J. BARNETT[2]

During the 1931 session of the Kansas Legislature, representatives of the fruit growers of northeastern Kansas and the potato growers of the Kansas river valley appeared before committees of the House and the Senate and asked that experiment farms be established in that section of the State. Their reasons for this request were that many practical problems arising in the production of tree fruits, small fruits and potatoes were peculiar to that section of Kansas and could be studied to better advantage under the environment of soil and climate existing there than they could elsewhere. Cited also were the facts that soil management, insect and disease pests, varieties, seed and plant sources, pollination, preparation of products for market and the pruning of young fruit trees were among the most pressing of these problems. They mentioned, too, the success of this type of experimentation in southeastern Kansas and in the Branch Stations farther west.

As a result, legislation was enacted authorizing the Director of the Agricultural Experiment Station to establish such farms and appropriating funds for their support through the next biennium. Four farms were established in time to get the work under way in the spring of 1932. One of the farms was located in Atchison county and was known as the Atchison Farm or the Atchison Experiment Orchard.

This orchard was located 10 miles south of Atchison and 15 miles north of Leavenworth, at the junction of highways U. S. 73 and Kansas 75. The land was owned by Mr. Matt Ernzen, a successful farmer of Oak Mills, Kans.

MEMORANDUM OF UNDERSTANDING

No purchase of land or erection of permanent buildings was contemplated when this orchard site was obtained. The work was planned and carried out under a simple Memorandum of Understanding between the Agricultural Experiment Station and the owner of the land. This agreement became effective January 1, 1932, and provided that the Experiment Station would bear all expenses, supervision, materials and labor, of growing an experimental orchard on a 12-acre tract of land on the farm of Mr. Ernzen. All intercrops grown were to be the property of the owner but he received no rent for the use of the land.

The orchard was operated under this memorandum until 1939, when it was revised to provide for sharing the yield of fruit with the owner of the land. The new memorandum pro-

[1]Contribution No. 184, Department of Horticulture.

[2]Superintendents of the Northeast Kansas experimental farms were T. Russell Reitz during the first three years and Erwin Abmeyer during the last six years. The data on which this report is based were collected under their efficient supervision.

vided that the Experiment Station should continue to care for the orchard as in the past but the fruit grown should be shared, one-half to the owner of the land and one-half to the Experiment Station. The revised Memorandum of Understanding continued in force until the orchard was abandoned by the Agricultural Experiment Station in October, 1941.

THE ORCHARD SITE

Soil. —Important items in the choice of an orchard site are soil, water drainage, air drainage, aspect or slope and exposure to prevailing wind. The soil of this site belongs to the Marshall Series. It is of glacial origin being derived from glacial sediments probably reworked first by water and later by wind. The top soil is dark greyish or almost black and merges into a slightly tight, light brown subsoil at about 18 inches beneath the surface. This merges into typical loessal material. On one area of the tract glacial conglomerate is found. The effect of this will be discussed later.

This soil was of moderate fertility. Corn yields of 35 bushels to the acre could be produced when rainfall and other climatic conditions were favorable. No accurate history of its past use could be obtained but the belief was expressed by the owner that it had produced one generation of fruit trees many years previously. A somewhat uneven stand of red clover on the land was plowed under in the early spring of 1932. The soil was seriously eroded in only two places, along the west margin and slightly west of the center of the north slope where a small gully had started.

Drainage. —Water drainage of the tract was adequate. At no point did water remain on the surface long enough to become injurious and under-drainage was excellent. No water injury to the trees under straw mulch, a severe test, was detected at any time. Figure 1, although not a topographic map, shows the elevations of the parts of the orchard. Small terraces drawn between the rows of trees are on areas which would be in danger of erosion when the surface of the soil was bare. The southeast section slopes southward but not so steeply as to cause destructive erosion. Air drainage was adequate to protect the fruit blossoms from spring frosts during each of the three years the trees were in bearing.

Aspect.—This land sloped to the south, the west and the north. The crest of the hill began at Row 5 on the east margin and continued nearly west to Row 18 where it followed a northwest by west direction. This is roughly indicated by the terraces shown in Figure 1 all of which drain at both ends except the two short ones which slope only to the east. The most abrupt slope is to the north, from Rows 8 and 21. The aspect of the orchard was in general favorable.

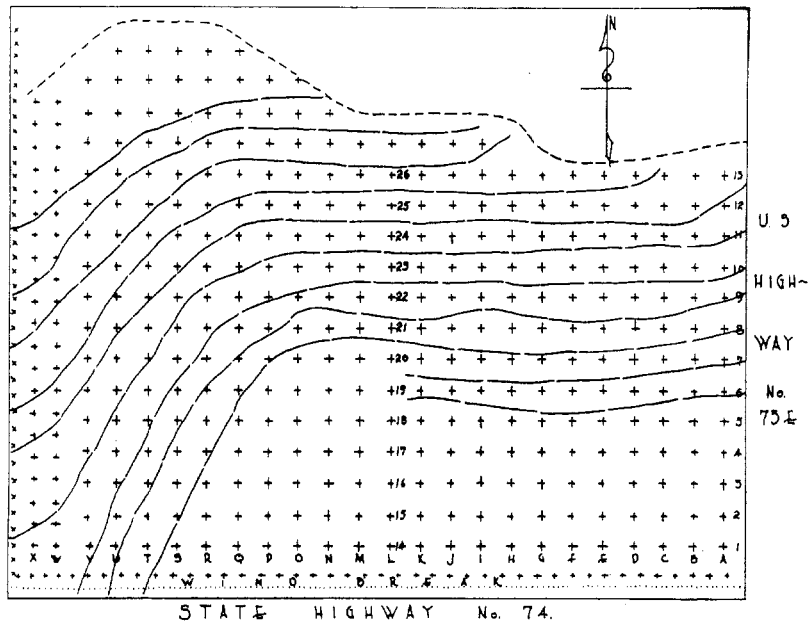

Fig. 1—Planting plan of the Atchison Experiment Orchard.

VARIETIES

NORTH AND SOUTH

Winesap	Rows A, B, C, L, M, N.
Jonathan	Rows D, E, F, O, P, Q.
Richared	Rows G, H, I, R, S, T.
Grimes	Rows J, K, U, V.
Montmorency	Row W.
Early Richmond	Row X.

SOIL MANAGEMENT

TREATMENTS—EAST AND WEST

Rows 1, 2, 3, 20, 21, 22	Clover
Rows 4, 5, 6, 23, 24, 25	Clean culture and cover crop (vetch)
Rows 8, 9, 10, 14, 15, 16	Clean culture and cover crop (cowpeas)
Rows 11, 12, 13, 17, 18, 19	Intercrop corn
Rows 7, 26	Straw mulch

WINDBREAKS

South—Pine (++) 20′, Chinese arborvitae (. .) 6′
West—Osage Orange (+++) hedgerow
.... Terrace

Wind Hazard. —The south and the west slopes and the crest of the hill in this tract were badly exposed to south winds. There was no natural barrier to break their force as a wide valley intervened between the orchard and the next range of hills. Because of this situation, tree windbreaks were established or maintained along both the south and the west margins of the orchard. These are described on page 25 of this publication.

PLAN OF THE ORCHARD

In 1931, when the Atchison Experiment Orchard was planned, the depression years were imminent but, in general, fruit growing was among the most prosperous types of farming. The Atchison district had recently planted 1,500 acres of commercial orchards, and those who proposed the legislation for the experiment fields and workers in the experiment station were of the opinion that large new orchards would be planted in the northeastern section of the State. For this reason this small orchard was planned to serve as a demonstration of some of the known principles of orcharding applied to the district and for experimental studies on practical questions the answers to which were not clearly known.

Utilization of the Land. — A study of the area available for this orchard indicated that soil and slope variations would make somewhat more than one acre situated in the northwestern corner of the tract unsuitable for experimental work. Windbreak trees on the south and the west boundaries were deemed worthwhile. This further reduced the experimental area. It finally contained slightly over 9 acres on which were planted 286 apple trees. Two rows of sour cherry trees occupied the west 70 feet of the tract. The cherries were under the handicap of competing with an aged hedge row of Osage Orange trees which marked the west line. Row V, Grimes Golden apples, was beyond the root effects of the hedge row. Reference to Figure 1 will aid in understanding the layout of the orchard.

Varieties Planted. — Experimental studies in the station orchards at Manhattan and 75 years of commercial orcharding had fairly well determined the adaptation of apple varieties to this section of the State. Jonathan had shown its leadership and constituted almost one-half of the plantings then in bearing. Winesap, the leader farther west in the State, was second in rank. Except for cross pollination needs and distribution of spraying and harvesting labor these two varieties might well compose an entire commercial orchard. They were both admitted to have serious faults, such as sus-

ceptibility to cedar rust and frogeye or black rot and premature dropping of the Jonathan and susceptibility to scab and tendency toward the production of small fruit of the Winesap, but were, even though thus handicapped, far in advance of other old, well-tested varieties. No question arose regarding the selection of these two varieties.

The list of varieties was expanded by the addition of Richared, a bud sport of Delicious, and Grimes Golden. These were both high quality varieties and were well known on local and general markets. It was expected that Richared would be tender to spring frosts and somewhat erratic in bearing due to other causes and that Grimes Golden would eventually suffer from its own special disease, collar rot. The Grimes Golden had been double-worked, having an intermediate stock of Black Twig, with the hope that their life would thus be prolonged. Many other varieties are nearly as well adapted and some are perhaps more profitable in eastern Kansas than Richared and Grimes Golden. Ben Davis, Gano, Black Twig, Stayman, York, Rome and Wealthy all have a place in commercial orchards but all have grave faults when grown in Kansas.

As finally planted the experimental part of the orchard contained 78 trees each of Winesap, Jonathan and Richared and 52 trees of Grimes Golden. Rows of varieties were planted on north and south lines and each variety occupied two blocks, one in the east and one in the west half of the orchard. Three-row blocks which the exigencies of the layout seemed to require for Winesap, Jonathan and Richared would not be recommended for a commercial orchard. Rows of trees were designated by letters: A, B, C and L, M, N were Winesap; D, E, F and 0, P, Q Jonathan; G, H, I and R, S, T Richared, and J, K and U, V Grimes Golden. All the trees planted had been propagated by a Doniphan County nursery and were of first grade quality. The cherry trees were one year of age and the apple trees two years. The circumference of the trunk, six inches above the soil line, was measured and recorded immediately after they were planted. Individual trees were designated by the number in the row and the row letter, as 2A or 22V.

Sour Cherry Planting.—Rows W and X were planted to sour cherry, W being Montmorency and X Early Richmond. These trees, and more especially row X, grew under the hardship of competition with the single row of large Osage Orange trees on the west border of the orchard. Certain records of their growth and yield of fruit were kept but their main purpose was to fill in this area which was worthless for experimental work with the apple. Twenty-one trees were planted

in each of these rows. Trees were identified by the method used for apple trees.

Experimental Plots. —The plots designed for experiments in orchard soil management were established east and west across the variety tree rows and numbered by half rows as shown on Figure 1. These plots were, with one exception, three tree rows wide and eleven trees long. The smaller plots, rows 7 and 26, were only one row in width and each plot consisted of 11 trees, or 22 trees under this treatment. The large plots each contained 33 trees and treatments were duplicated in each section (half) of the orchard. This afforded 66 trees for each soil treatment undertaken on these plots.

Plots for experimental pruning of young apple trees consisted of one row of each of the different varieties. There were under this plan three plots in each half or six in the whole orchard for Winesap, Jonathan and Richared. One of the treatments used with these varieties was dropped for Grimes leaving only two or, when duplicated, four pruning plots for that variety.

Both soil management and pruning experiments were extended to the two rows of sour cherry but hopes for reliable information were not high because of the poor site these trees occupied. This pessimism was later justified, though the row of Montmorency maintained itself fully as well as was hoped. Pruning treatments of the cherries were applied in the single row of each variety: treatment 1 to trees 1 to 6, treatment 2 to trees 7 to 12, and treatment 3 to trees 13 to 21.

EXPERIMENTAL PROBLEMS

The values of this orchard were planned to be both demonstrational and experimental, so the experiments undertaken were wholly of an applied nature. The superintendent had three other farms to supervise during the first two years and a fourth was added the third year. This heavy assignment reduced the intensity of study available for specific problems, and a reduction of the funds limited the employment of trained assistants to one, an entomologist. Pruning, pest control and orchard soil management were selected as the elements of orcharding which would yield the most valuable information to growers of young orchards in northeastern Kansas.

Tree Building Experiments. — Opinion in this region was well crystallized that, for most kinds and varieties of fruit trees, the modified-leader form of fruit tree is most desirable. A sound tree of this shape possesses the virtues of low stature, strength and productivity. Unfortunately, many growers who appreciated the value of the modified-leader type of fruit

tree and attempted to train their trees to that form have failed to obtain it.

One of the important requirements for the production of a modified-leader form fruit tree is the preservation of the leader through the formative years. With certain species as the sour cherry and some varieties of apple the tendency of the side or framework branches is to "choke out" the leader and this results in a tree of another form. Because of this hazard, as well as for other reasons, the number of first growth framework branches left on the tree is important. The requirements for these branches are that, whatever their number, the points of origin shall be well distributed both vertically and around the central stem of the tree, that branches of comparatively good vigor shall be selected and that one of them must protect the southwest side of the trunk against sunscald and flatheaded borers. The tendency of cherry trees during their first year's growth in the nursery is to force secondary growth by 4 to 6 or more buds in a short space on the original stem. The location of this growth area probably is influenced by the density of the stand, is a light effect. Bud propagated apple trees, especially if irrigated, have a similar growth habit during their first year in the nursery, whereas bench grafted apple trees often delay the production of lateral branches until their second year of growth. In the Atchison orchard, this selection of original framework branches was made at the time of pruning immediately following planting of the tree when all except the specified number of side branches were removed and those remaining on the tree as well as the leader were headed back moderately.

The following trees were pruned to three framework branches when set: Winesap, rows A and L; Jonathan, rows D and O; Richared, rows G and R, and Grimes, L and U. Two framework branches were retained on the following trees: Winesap, rows B and M; Jonathan, rows E and P; Richared, rows H and R, and Grimes, rows K and V. Four framework branches were saved on the following trees: Winesap, rows **C** and **N;** Jonathan, rows F and Q, and Richared, rows I and T.

The effect of this variation in the amount of wood removed and retained might have been measurable in the subsequent annual growth of the trees, so growth records were checked against the pruning given. The real test, however, would be seen in the form and strength of the bearing trees. This answer was just over the horizon when the orchard was lost.

Spraying Experiments. — Rather elaborate spraying experiments were carried on in the Northeast Experiment farm at Blair. Both materials and schedules were investigated there in a bearing orchard. The plan for the Atchison or-

chard was to give the trees full protection against pests but to delay the beginning of any extensive spraying experiments until after the trees came into bearing. Serious outbreaks of insects, rodents and fungous diseases did occur during the juvenile period of this orchard and will be discussed briefly, with the control measures followed, under other headings.

SOIL MANAGEMENT EXPERIMENTS

Four or perhaps more general methods of managing orchard soils are practiced in Kansas. In the Atchison orchard, experimental plots representative of four methods of orchard culture were established. The plan was to follow these methods strictly until the orchard came into bearing, then to revise the treatments better to fit the needs of bearing trees.

Straw Mulch Method.—Straw mulch as a method of soil management was applied to rows 7 and 26. The expectation was that straw would be difficult to obtain in this neighborhood so the minimum number of trees was given this culture. It consisted of the application of a 4- to 6-inch layer of wheat straw annually and over sufficient area to cover the spread of the tree roots. The circle covered around each tree trunk was 8 feet in diameter the first year and was widened each year until the sixth year when the mulch was continuous in the row and was the planting distance in width. Because of the increase of wheat production in the region of this orchard during the drought years, no difficulty in obtaining straw for mulching was experienced.

Red Clover Treatment. —The red clover treatment was used on two three-row plots, rows 1, 2, 3 and 20, 21, 22. The seeding was done in the spring on a well prepared seedbed in strips 20 feet wide between rows in each plot and 10 feet wide on the margins of the plots.

Various methods of disposing of the growth of red clover were planned but weather conditions so lessened the growth of this intercrop that these sub-treatments were impractical in application each year. On one row in each plot the red clover was to be harvested and removed as hay; on another it was to be cut on the same date and allowed to lie as a mulch, while that on the third plot was to be placed in circles around the tree trunks as mulch.

These red clover plots were established on land which sloped so steeply as to cause an erosion hazard. The west plot, rows 20, 21, 22, was terraced in October of the first year, but the east plot, rows 1, 2, 3 was not terraced and these strips of uncultivated clover and wild grasses were expected to control both sheet and gully erosion on this slope while allowing clean cultivation of strips about 7½ feet wide on each side of the tree rows. While the trees were small the

row itself was "figure 8ed" and later surviving weeds were hoed out.

Intercrop Treatment. —Many orchards in northeastern Kansas are planted to some row crop while the trees are young and experience indicated that neither their tops nor roots seriously interfere with such use of the strips between rows. Corn, strawberry, raspberry, potato and tomato are commonly used. Of these field corn was selected as the intercrop to grow on two plots, east, rows 11, 12, 13 and west 17, 18, 19. It was used because it is an adapted crop in that region, finds a ready market and requires a minimum amount of labor for care and harvesting. The soil was prepared each year and the corn was surface planted about May 10; six rows of corn were first used in each full space between tree rows and three rows in each half space on the margins of the plots. The number of rows of corn was reduced as the spread of tree roots increased.

In 1937 the corn was replaced in the east plot by Korean lespedeza. Reasons for this substitution were the failure of corn growth due to droughts and the general interest in lespedeza as an orchard legume. The non-experimental portion of the orchard, the northwest corner below row 26, also was planted to lespedeza.

Cover Crops. —Four plots in the orchard, 33 trees each, were placed under the clean cultivation plus cover crop method of soil management. Earlier work[3] at Manhattan had indicated winter vetch as the best of the legumes for this use so two plots, rows 4, 5, 6 and 23, 24, 25, were to be planted to this cover crop each August at the rate of 30 pounds to the acre covered, and the growth incorporated in the soil the following May.

Cowpeas were selected as the other cover crop plant. The procedure with it was to plant in July, 90 pounds to the acre, and allow the dead stubble to occupy the spaces between tree rows until early spring. Cowpeas were planted in rows 8, 9, 10 and 14, 15, 16.

EXPERIMENTAL RESULTS.

The first six to 10 years in the life of an orchard in Kansas is a period of vegetative development the success of which cannot be determined accurately until the productive life of the trees has given the answer, 10, 20 or 50 years later. Not until that time can a test of the strength built into a tree during its formative period finally be tested and not until that time can the experimenter or the grower read the final an-

[3]Barnett. R. J. Growing an Orchard in Kansas. Kans. Agr. Expt. Sta.., Bul. 290 pp. 34-40.

swer to soil management treatments. Broken trees as they approach maturity, a spotted stand of trees, small size or poor color of leaves or fruit, blister canker incidence, and various degenerative ills could be correlated in a long-time experiment with events or treatments which occurred or were applied many years earlier.

The two principal experiments established in the Atchison orchard, pruning and soil management, both required long, continuous prosecution before results approximating final answers to the questions underlying the experiment could be given. The orchard was lost due to an untimely and unprecedented freeze just as it was coming into bearing and early indications of what the answers were to be from a

Fig. 2—The row of apple trees on the left has been under straw mulch treatment since planting. The row on the right, of the same varieties, has been clean cultivated with a few good yields of winter vetch worked into the soil. Note the comparative growth during a period of deficient rainfall, 1932-1939.

young bearing orchard grown under known environmental conditions, modified in a few important ways, were all that remained.

Records in this orchard were taken on the individual tree basis throughout the nine years. These are too voluminous to copy, especially those on tree growth, so observations and summaries based on them are used in this report. It has been recognized that recorded measurements accompanying variations in varieties, pruning, soil management, or rainfall are sometimes narrow and sometimes wide and are subject to the inaccuracies found in all except the most rigorously controlled field experiments.

VARIETY PERFORMANCE

Fruit yields for the four varieties of apple planted in the Atchison orchard have been compiled from the individual tree records and are shown in Table 1. The first variety to come into bearing and the heaviest producer each of the three years apples were borne was Winesap. In 1938, 63 of the 78 Winesap trees in the orchard matured fruit. Tree yield varied from "sample" fruits to 58 pounds on tree 8C. During the same year this tree increased 3.25 inches in trunk circumference, an average growth.

Winesap maintained its leadership in fruit production in 1939 and 1940. For the three-year period these 78 trees gave an average tree yield of 156 pounds, or, omitting replants too young to bear, 195.3 pounds for each bearing tree. The "big blow" on September 3, 1939, affected the Winesap apples less than the earlier varieties but 40 percent of them were blown from the trees.

Jonathan was in second place. It bore fruit in 1939 and 1940. Average yield for trees planted was 89.5 pounds a tree and 134 pounds from those in bearing. Only 25 percent of the Jonathan fruits clung to the trees until harvest time in 1939. Experience had indicated that Jonathan was more precocious than Winesap but the records from this orchard do not confirm that indication. The fruit was excellent in both size and color in 1940.

Richared bore its first fruit in 1939 when 51 of the 73 trees planted produced 3,269 pounds, nearly all of which dropped from the trees September 3 or soon after. The 1940 crop was lighter but the apples were of excellent size and color. For the two years during which Richared produced a crop the average yield was 91.96 pounds per bearing tree.

Grimes gave the lowest production record of the four varieties. Average tree yields were 55.6 pounds from the 52 trees in the orchard and 81.1 pounds per bearing tree for the two years 1939 and 1940. Grimes, like the other two early winter varieties, dropped its fruit badly in 1939 but yielded excellent fruit in 1940. The trees of this variety were free from disease during the entire life of the orchard.

PRUNING; TREE BUILDING

Results of variations in pruning the young trees in Atchison orchard were expected after the trees became mature and had produced a number of heavy crops. Due to the loss of the orchard at the age of nine years, this experiment proved of minor value.

The growth records of the trees were tabulated on the

Table 1. Yield of Fruit, Variety Basis.

Crop Year	Winesap		Jonathan		Richared		Grimes	
	Bearing trees number	Yield pounds	Bearing trees number	Yield pounds	Bearing trees number	Yield pounds	Bearing trees number	Yield pounds
1938	63	1104						
1939	69	7760	51	5480.5	51	3269	35	1539
1940	55	3307	53	1502	46	1191	36	1353
Average number	62.3		52		48.5		35.5	
Total yield		12,171		6,982.5		4,460		2,892
Yield per bearing tree		195.3		134.0		91.96		81.1
Yield per tree planted		156.0		89.5		57.18		55.6

basis of the number of framework branches retained at the first pruning. No valuable correlation was found between these two sets of data. Increase in circumference was at practically the same rate for trees pruned to two, three or four framework branches at time of planting and all given the same general pruning in subsequent years.

Observation showed that trees which would be classed as good, intermediate and poor in form were to be found among

Fig. 3—An example of a young Jonathan tree which was pruned to four framework branches when planted.

the trees in each pruning group. It did appear, however, from a study of the trees so started that four framework branches were too many to leave on trees which had been grown the second year in the nursery. The branches are crowded for vertical space and tend to pinch out the leader. The tree in Figure 3 is one of the better trees in this group, and the lower framework branch on it will soon be shaded out or will bend down to the ground. The farmstead where the rain gauge was located may be seen in the background of this view.

Figure 4 illustrates a Jonathan tree pruned to two framework branches. These original branches are at too nearly

the same height on the trunk and form narrow angles with the main stem, especially for Jonathan. Four additional and well placed framework branches are shown on this tree. Its subsequent growth and behavior under heavy loads of fruit would have made an interesting study.

A Grimes tree started with three well distributed framework branches is shown in Figure 5. The branch to the left, southwest, seemed to dominate the main stem even though it is the lowest branch; an unusual habit of growth in this orchard.

Fig. 4—Only two framework branches remained on this Jonathan tree after its first pruning.

Trees grown with a corn intercrop were less deformed by wind and more easily trained to the desired form than those under other kinds of soil management. This seemed true despite the fact that the corn block of the western half of the orchard was near the point of greatest elevation.

Another established principle of pruning was verified in this orchard during the drought years. Pruning is of little value in modifying the form of a tree when the growth is

slow. Vigor and form are closely allied in tree growth and only vigorous trees will respond to the efforts of the pruner. Between the years 1933 and 1937 these trees were pruned very lightly because these were the drought years. In fact, the removal of water sprouts and an occasional crossing branch was all the cutting that was done. In 1938 to 1940 inclusive top growth was more abundant and greater effort was again made in shaping the trees to the desired type.

Fig. 5—This Grimes tree was pruned to three framework branches at planting time.

SOIL MANAGEMENT DATA AND RESULTS

In measuring the effects of various methods of soil management, the criteria most commonly used are differences which may develop in the soil itself and the varying responses of the trees. The use of both measures was planned for this study in the Atchison orchard. Moisture content and available nitrates of the soil were to be determined as indications of the effects on the soil itself of the different methods of management. The former, soil moisture determinations, was continued through the whole period but the second, nitrate determinations, was abandoned after the first year because of lack of funds.

Plant responses due to different methods of soil management in this orchard were recorded and seemed to present a measure of the efficiency of the different methods on this site and under the unusual climatic conditions of the past decade. The vegetative growth of the trees as indicated by the annual increase in tree trunk circumference and the yield of fruit during the last three years constitute the records taken on tree response.

Rainfall Records. —A rainfall gauge was established at the Ernzen home one-fourth mile north of the orchard and records of precipitation for the months April to October inclusive were kept each year except 1933 for which no report is available. The data used for this season were copied from Weather Bureau reports for Atchison, Kansas. Table 3 shows the monthly and total rainfall for the growing season of each of the nine years this orchard was used for experimental work.

Table 2. Monthly Rainfall in Inches. Growing Season.

Year	April	May	June	July	Aug.	Sept.	Oct.	Total
1932	4.07	3.06	5.16	4.04	4.66	4.13	0.56	25.85
1933	1.72	3.40	4.12	2.86	6.03	2.49	0.91	21.53
1934	1.72	3.33	3.11	1.83	1.77	6.13	1.85	19.74
1935	1.48	6.35	5.63	0.42	2.23	6.31	1.30	23.72
1936	4.06	6.38	1.73	1.06	0.95	8.80	0.86	23.84
1937	1.61	2.36	3.39	5.70	1.60	1.50	1.59	17.75
1938	0.67	5.32	2.03	5.63	5.90	1.88	0.13	21.56
1939	2.76	1.02	6.36	0.63	3.71	0.50	1.26	16.24
1940	2.99	4.77	4.60	3.85	6.53	1.32	1.95	26.01
Total	21.08	35.99	36.13	26.02	33.38	33.06	10.41	196.24
Average	2.34	3.99	4.01	2.89	3.71	3.67	1.15	21.80

The first and the last years of the period under study had near normal rainfall in both total amount and distribution through the growing season, while many other seasons showed wide departures from the normal. The season of 1934 brought the first destructive drought in this locality. The total rainfall was low but the injury was caused by the deficiency in July and August combined as it was with high temperature and low relative humidity of the air. Rain fell on eight dates in August but only that of August 15 was of sufficient amount, 0.64 inch, to penetrate the straw mulch. Red clover and corn were killed but the fruit trees did not suffer badly.

A comparison of the rainfall of 1935 and 1936 shows some points of interest. The total amount was nearly the same,

23.72 inches in 1935 and 23.84 in 1936, but the dry periods were in extreme contrast. In June, the critical month for tree growth, 1935 had 5.63 inches of rain. This was followed by an extremely dry July and no soaking rains in August. These young trees did not suffer for lack of water. In 1936 May and September had heavy rains but the three summer months were all low although one-inch rains fell on both June 5 and July 27, the latter being the only measurable amount for that month. This meager mid-season rainfall coincident with extremes of temperature and aridity caused the most destructive drought the locality had ever known. Annual plants, orchard trees and many forest trees perished. Eighteen apple trees in this orchard were so injured as to require their removal within the next year. The comparison of these two years illustrates the futility of trying to evaluate growing seasons on the basis of total rainfall alone.

Table 3. Soil moisture percentage content, dry soil basis. Averages of the top three feet samples taken monthly through the growing season.

Year	Soil Treatment					
	Red clover sod	Straw mulch	Cover crop winter vetch	Cover crop cowpeas	Intercrop corn	Intercrop or sod K. lespedeza
1932	26.10	27.32	28.64	19.98		
1933	19.70	21.88	21.55	18.72	17.31	
1934	16.66	19.31	16.72	16.68	16.28	
1935	19.72	19.46	20.00	17.05	15.10	
1936	19.28	23.85	24.92	23.73	21.67	
1937	23.85	25.87	26.21	25.10	22.99	15.89
1938	26.56	23.70	25.26	25.60	24.10	18.93
1939	20.53	24.33	24.74	22.13	22.06	17.53
1940	26.36	25.63	27.36	26.43	26.70	21.03
Av.	22.08	23.48	23.93	21.71	20.77	18.34

Both 1937 and 1939 were low in total rainfall during the growing season but an adequate supply in July, 1937, and in June and August, 1939, prevented losses which might have been expected because of the low total. The distribution of the rainfall saved these crops, though the "big blow" later proved disastrous to that of 1939. Response of the trees was much alike in 1938 and 1940, although the earlier years had nearly five inches less rain during the season. Excessively heavy rains were not common during this period. The fastest 24-hour fall was March 31, 1939, when the reading was 5.03 inches. Other excessive records were 4.32 inches July 12, 1937, 4.05 inches July 16, 1938, 3.45 inches May 27, 1935 and 3.00 inches June 13, 1940.

Soil Moisture. — Determinations of the percentage of moisture, dry soil basis, were made during the growing season of each of nine years in the Atchison orchard. One-foot layers to a depth of three feet were tested and during the first year, when rainfall was abundant and well distributed and the trees' effect unimportant, showed the soil well supplied with water, although the July planted cowpeas had reduced the soil moisture in those plots to the minimum measured that season.

As shown by Table 3, the soil on the cowpea plots was the only one that fully regained its original moisture during the nine-year period. The two treatments which approached a condition of sod, red clover and Korean lespedeza, often caused a shortage of soil water, whereas the straw mulch and the winter cover crop, winter vetch, best conserved it. Cowpeas and corn both competed with the tree for moisture during August, if moisture were present to permit their growth. Winter vetch was planted in late August or early September, so, as far as the trees' demand for water was concerned, this method approached the so-called clean cultivation method. In both red clover and Korean lespedeza plots, crabgrass frequently was mentioned as making a heavy late summer growth. This would add to the depletion of water in these plots.

Permanent wilting is not recorded as having occurred in the trees on any of these plots during the years of extreme drought. In 1936, the minimum soil moisture determinations were found in July or August when the rainfall for the three summer months was only 3.74 inches, most of which came as light, ineffective showers, and when the temperature and evaporation rate were at a maximum. These minima were as follows: Red clover 11.86 percent, straw mulch 21.74, winter vetch 21.73, cowpeas 18.80 and corn 16.18. Nearly all annual plants and many perennial grasses were killed by this drought.

As shown in Table 3, the Korean lespedeza plot was the driest during the four years it occupied the original corn plot in the east half of the orchard. Its average moisture content for the four seasons, 1937-1940, was 18.34 percent. The fact that the soil in part of this plot shows coarse glacial conglomerates, which has a lower water holding capacity, explains in part this variation but the sod effect also contributed to it.

Soil Management and Tree Growth. —The relation between the various methods of soil management and the growth of the apple trees is shown in Tables 4 and 5. The

data in these tables are condensed from individual tree measurements, using the trunk circumference about six inches above the ground level as the criterion. In Table 5 the average annual increases in trunk circumference of the trees are added and the total average growth of trees under each soil treatment is computed. The same result is shown in Table 4 by subtracting the measure of the trees at the time they were planted in each block from the final measure of the same trees after growth was completed in 1940. The results obtained in these two ways differ slightly and when the whole period is considered, Table 4 is the more nearly accurate. Seasonal effects on tree growth are shown in the annual records of Table 5.

Table 4. Tree growth under various methods of soil management. Basis, trunk circumference.

1932-1940

Method	Trees set number	Average size when set; in.	Trees surviving 1940; number	Average size inches	Average gain in size inches
Red clover sod	66	2.40	47	18.76	16.36
Winter vetch, c. c.	66	2.41	54	20.12	17.71
Cowpeas, c. c.	66	2.42	61	20.50	18.08
Corn, intercrop*	66	2.49	61	21.60	19.11
Straw mulch	22	2.40	19	24.96	22.56

*Under this treatment the west plot was planted to corn each of the 9 years, whereas the east plot was planted to corn 5 years and to Korean lespedeza the last 4 years.

The order of the results due to varying the soil management, as shown in Table 4 from red clover giving the smallest to straw mulch giving the largest growth, is fairly regular and no wide difference is to be seen between adjacent measurements. When the poorest and the best trees are compared, however, the difference is rather great. One could not fail to see by observation of the trees that those grown under straw mulch were larger than those in the red clover plot but he would need to have looked closely to see that there was a difference between the trees on any two adjoining plots, as winter vetch and cowpeas or intercrop and straw mulch. Difference between the size of trees under straw mulch and winter vetch treatments is obvious in figures 2 and 7a.

There would seem to be some lessons in the data given in Table 6 aside from the mere rank of the various soil management methods. The growth of trees was less depressed

in the more severe drought and heat season of 1936 than in 1934. Time of onset of dry soil may explain this anomaly. Reference to Table 3 will show that the spring rains were more abundant in 1936 than in 1934. The fact becomes significant when the periodic growth of apple trees is considered. Their principal enlargement occurs in May and June and was completed before the severe weather of 1936 arrived. In contrast soil moisture was low in the period of rapid growth during the season of 1934 and this probably accounts for the low average gain made by the trees that year.

Table 5. Average annual growth of apple trees under five methods of soil management.

Year	Circumference increase, inches				
	Sod red clover	Cover crop winter vetch	Cover crop cowpeas	Intercrop	Straw mulch
1932	.61	.79	.68	.72	.77
1933	1.69	1.55	1.60	1.84	2.12
1934	1.06	1.00	1.13	1.33	1.68
1935	1.21	1.47	1.61	1.68	2.01
1936	1.39	1.76	2.00	2.07	2.34
1937	2.05	2.28	2.36	2.48	3.18
1938	2.87	2.94	2.92	3.00	3.77
1939	2.11	2.28	2.39	2.49	3.16
1940	2.86	2.90	2.96	2.84	3.15
Total	15.85	16.97	17.65	18.45	22.18
Annual Average	1.76	1.88	1.96	2.05	2.46

Fruit was borne on many of these trees in the last two years. Rainfall, soil moisture and annual growth were all low in 1939 even though the rains were unusually timely. In 1940, when a heavier crop was produced, soil moisture was abundant but on only one plot, winter vetch, did tree growth equal that of the nearly cropless year of 1938 when the season's rainfall was smaller but well distributed. It would appear that tree growth was slowing down as fruit bearing increased in this orchard.

Fruit Bearing and Soil Management.—A second tree response to the variations in orchard soil management was that of fruit yields. Following about the tenth year of soil treatments this measure would tend to surpass tree growth in importance. In it would be found the final answer to the relative values of the different methods. It is even a measure of the size and longevity of the trees because through the long life of an apple orchard only large trees and a full stand of them can excel in yield of fruit.

In this orchard a light first crop was produced only on Winesap trees in 1938. In 1939 Winesap and the other varieties bore a fair crop for trees of their age but this crop was nearly all lost in the "big blow" of September 3. These two crops were carefully harvested and weighed despite their lack of commercial value. The crop of 1940 showed the promise of this small orchard and was carefully harvested, weighed, graded as to size of fruit, and color noted for each individual tree. From the yields of the three years, the data in Table 6 were compiled. Table 1 was compiled by a different arrangement of the same records. From Table 6 it can be seen that the order of yield per bearing tree under the various methods of soil management is as follows: Red clover, winter vetch, cowpeas, intercrop and straw mulch. This is the same relative position shown in the last column in Table 4 and indicates that tree growth and tree yields are affected in a similar manner by variations in soil management, at least while the trees are young.

Table 6. Fruit production under various methods of soil management. 1938, 1939 and 1940

Method	Trees set, number	Trees bearing fruit, number*	Fruit grown, pounds	Fruit per tree set, pounds	Fruit per bearing tree, pounds
Red clover sod	66	101	3,646	55.2	36.0
Winter vetch, c. c.	66	107	3,804	57.6	35.5
Cowpeas, c. c.	66	112	5,965	90.3	53.2
Intercrop	66	100	7,497	113.5	74.9
Straw mulch	22	42	5,711.5	259.6	126.9

*Total for three years.

The last column, fruit per tree set, more strongly emphasizes the values of a straw mulch during a period of relatively dry years; more trees lived, they were larger in size and they bore more fruit. Drastic revision of these results might have been necessary had it been possible to continue these experiments through two or three more decades and a repetition of this work on soil managment in an orchard planted in 1942 might give different results when measured 10 years later.

SOME INCIDENTAL RECORDS.

Windbreaks. —In 1932 when the orchard was planted a single row of closely planted mature Osage Orange trees marked its entire west margin as shown in Figure 1. The question of the removal of this row of trees was given serious

consideration. Favoring its removal were, (1) the loss of land use due to the wide superficial spread of the roots of this species and their ability to absorb water and nutrients in competition with fruit plants and (2) the San Jose scale hazard to the apple trees due to their proximity to this favorite food plant of that insect. Arguments against its removal were the protection this row of trees might afford against winds from the west or southwest and the facts that they were not infested by the scale nor was this insect found on any host near the orchard site.

Fig. 6—This windbreak protecting the south side of the Atchison experimental orchard was planted at the same time as the apple trees and has surpassed them in rate of growth.

This windbreak row was left undisturbed and the west row of adjacent apple trees was set beyond the soil area occupied by the roots of the Osage Orange. An attack by San Jose scale at any later time would have necessitated the removal of this windbreak because of difficulty of controlling that pest on large, dense trees.

The south margin of this orchard was exposed to the prevailing south winds of the region. A windbreak of trees was established since it was considered of enough value to compensate for the use of the land it occupied. This strip was two rows of trees wide. The south row was of Chinese arborvitae and was set 15 feet inside the orchard line, 6 feet apart; at 18 feet north of the arborvitae was the row of Scotch pine set 20 feet apart. These trees were planted the same spring

as the orchard trees and have proved excellent as a windbreak. Their growth is shown in Figure 6 which is from a photograph taken in 1940. Neither of the species in this strip suffered permanent injury from either the drought years or the untimely freeze of November, 1940. A true evaluation of the strip could not be made until the orchard reached maturity but recent studies indicate greater values of the Black Pine or the Western Yellow Pine as a substitute for the Scotch Pine.

Terracing. —The north and west slopes of the Atchison orchard were terraced during October 1932 after one year's growth of the trees. The lines of these terraces are shown in Figure 1. They were narrow, had to be abrupt and high wall in places to avoid overflow, drained at both ends except the two short ones, were expensive to maintain and interfered with cultivation and spraying especially on the northwest slope where their direction was diagonal to that of the tree rows.

In 1933 the superintendent's report mentioned that the tractor cultivation so leveled the terrace walls that rebuilding was necessary. He did not note any break in them that year. Permanent outlets were built in 1934 and breaks near the angles in the terraces are mentioned. A gully two feet deep near trees 8J to 12J had been filled in but required attention to prevent breaks. Special trouble with the terraces was not again experienced until the 4-inch rain of July 16, 1938. This rain caused some bad breaks but none of them through more than one terrace.

These terraces are more than once referred to as a "necessary evil". Grass channels were suggested as a substitute but the terraces were maintained-until the orchard was abandoned in 1941. The final answer to the erosion problem in orchard lands in northeastern Kansas has yet to be found.

Pests of the Young Orchard. —Pest control studies were not planned for the Atchison orchard but it was realized that a young orchard is always subject to injury by both plant diseases and insects. Standard methods of control were to be used for such pests as appeared. These treatments followed no regular schedule but were applied whenever the presence of the pest indicated a need for them.

Rodent damage also required preventive measures. For this purpose wire guards were placed around the tree trunks and rabbit injury was thus avoided until the fall of 1939 when the tree trunks filled the guards, requiring their removal. This was done at the time the trunk circumference measures were taken and the bands were not replaced. The winter of 1939-1940 was one of severe temperature from

December 29 to February 29 and snow 6 to 10 inches in depth covered the orchard. During February 75 apple trees were severely gnawed, many of them from near the ground line to the framework branches, by cottontail rabbits. This injury was confined almost wholly to the cowpea plot, rows 14, 15 and 16, on which the stubble was dense, and to the adjoining corn plot rows. Exposed wood and inner bark were painted as soon as the injury was discovered and considerable bridge grafting was done. All the fruit which set on these girdled trees was removed early in the season. The bridge grafting was not widely successful but this combination of treatments saved the life of all but two of the injured trees, though the loss of six others of these injured trees was later attributed to this cause.

Poisoned grain in tin cans placed near the trunk of each tree under straw mulch prevented mouse injury throughout the whole period.

Spring canker worm control required an early spray of arsenate of lead each year. After the first year, apple scab became sufficiently abundant on the Winesap and Richared trees to require fungicidal sprays and light outbreaks of the leaf form of black rot on Jonathan trees were successfully combated. In 1940 a regular spray schedule was applied and codling moth was controlled. Some scab injury occurred.

Hordes of grasshoppers attacked the orchard in 1935 and largely defoliated the trees by early fall despite efforts to control them. Standard poison bait and arsenical sprays on the trees were used but the insects flew to the orchard in such great numbers that the survivors did great damage. Similar defense measures prevented damage in 1936 although the grasshoppers were again abundant. Defoliation in 1935 may have lessened the value of the growth records for that year and 1936 but the superintendent's reports indicate that the loss of leaves was uniform in the various parts of the orchard.

Thinning Fruit from Apple Trees. — Although none of the varieties in the Atchison orchard was distinctly biennial in the habit of bearing, plans were made to prevent part of these trees from ever producing an excessively heavy crop and to note the effect this treatment might have on regularity of bearing, length of life and total life-yield of the trees.

Thinning experiments were instituted in 1939 when the first normal set of fruit occurred. Winesap, Jonathan and Richared were divided into three plots and thinned as follows: Two rows, clusters thinned to one apple each; two rows, not thinned and two rows thinned to a distance of 6 to 8 inches between fruits. The number of leaves per fruit resulting from these thinning operations was not determined.

On Grimes, of which only four instead of six rows had been

planted, two rows were not thinned and two rows were thinned to a distance of 6 to 8 inches between fruits. Much of the fruit dropped on September 3, 1939, but the weight and size were recorded. These data show no definite results from the thinning. In the main, the unthinned plots set only one fruit to the spur and so differed but slightly from the cluster thinned plot. Thinning to 6 to 8 inches between fruits reduced the yield, when compared with the unthinned trees, and showed no increase in size of the fruit.

The thinning work was continued in 1940 using the same plots. Results were similar to those of 1939 with respect to yield and size of fruit harvested. Time required to thin and to harvest the fruit from the same trees later was recorded this year. Breaking up clusters required more time searching for apples to remove than in actual thinning. Time required for thinning 20 winesap trees in this way was 28 minutes. Only 221 apples were removed from these trees. To thin 1,501 apples from 16 Winesap trees, on the 6 to 8 inch plot, required 84 minutes. Time required to harvest the crop from these trees was recorded and little effect was traceable to the thinning. Other varieties gave similar results.

As was anticipated, this experiment indicates that any values from thinning the fruit borne by young, vigorous apple trees will have to come in later years. It probably should be deferred until the first year a really excessive crop of fruit is set.

Loss of Apple Trees. — In any young orchard the maintenance of a full stand of trees is an important and sometimes a difficult problem. After an orchard reaches bearing age missing trees are reestablished only at considerable expense and surrounding trees do not increase in production sufficiently to equal the loss of crop which missing trees would have produced.

Only one tree was lost from those planted in the Atchison Experiment orchard during each of the first two years. Tree 13B was replanted in the spring of both 1933 and 1934. The hot, dry summers of 1934 through 1937 took a heavy toll of the trees in this young orchard. In the spring of 1935 four replants were set and by fall five trees were marked as dead. Eight replants were set in 1936 but only one of these survived and 11 trees were marked for removal in the fall; actually 18 trees were planted in the spring of 1937. In 1938 five trees were lost, in 1939 three, and in 1940 eight. All the lost trees of 1940 had been girdled by rabbits and were former replants.

The record is not wholly clear but it appears to show a loss from all causes of 51 trees during the nine-year period.

About 35 of these were charged to drought; rabbit injury was second in this destruction with eight trees. Two replants were "tractored out" leaving six losses unassigned to any specific cause. The orchard originally contained 337 apple trees, so the loss was 15 percent during a period when climatic conditions eliminated many other young orchards in that part of the state.

Freeze of November, 1940. — After the abundant harvest of 1940, to which all the trees in the orchard which had persisted from the original planting contributed, the orchard appeared to be in excellent condition. The trees had made good vegetative growth and the foliage was abundant, free from disease and of good color. The set of blossom buds for the 1941 crop was heavy.

The month of October, during which fall frosts usually occur in the eastern section of the state, and the first part of November had passed with no weather condition arising to halt any of the physiological activities of the orchard trees. During the period November 10 to 13 temperatures of near zero came in with a high north wind and a small amount of snow. This sudden change from growing to arctic temperatures proved disastrous to nearly all the fruit trees in the Atchison orchard as well as in most other parts of the northern half of Kansas.

Nearly all types of winter injury described in horticultural literature could be observed. Young wood showed black heart, twig and bud killing was common, many trees showed severe crotch injury, and death of the bark and cambium layer on the trunks and framework branches was widespread in all orchards. Some of these types of injury are illustrated in figure 7. They were most severe on vigorous trees in well managed orchards.

Examinations of the Atchison Experiment Farm at intervals through the winter and spring months showed the destruction to be so widespread that the future use of this young orchard, which had been carefully and successfully nursed through the hottest and driest period the region had ever undergone, was entirely destroyed for experimental purposes. By the fall of 1941, less than a year after the freeze, a check-up showed the following losses: Winesap 61 trees dead and 17 injured of 78 in the orchard, Richared 76 of 78 trees dead, Jonathan 26 dead and 52 injured of the 78 planted and Grimes 34 dead and 16 injured of 52 trees planted — nine years of production work and many years of future use annihilated in four brief days of blizzard. These were followed by a winter so mild that no frost penetrated the soil beneath a straw mulch at any time.

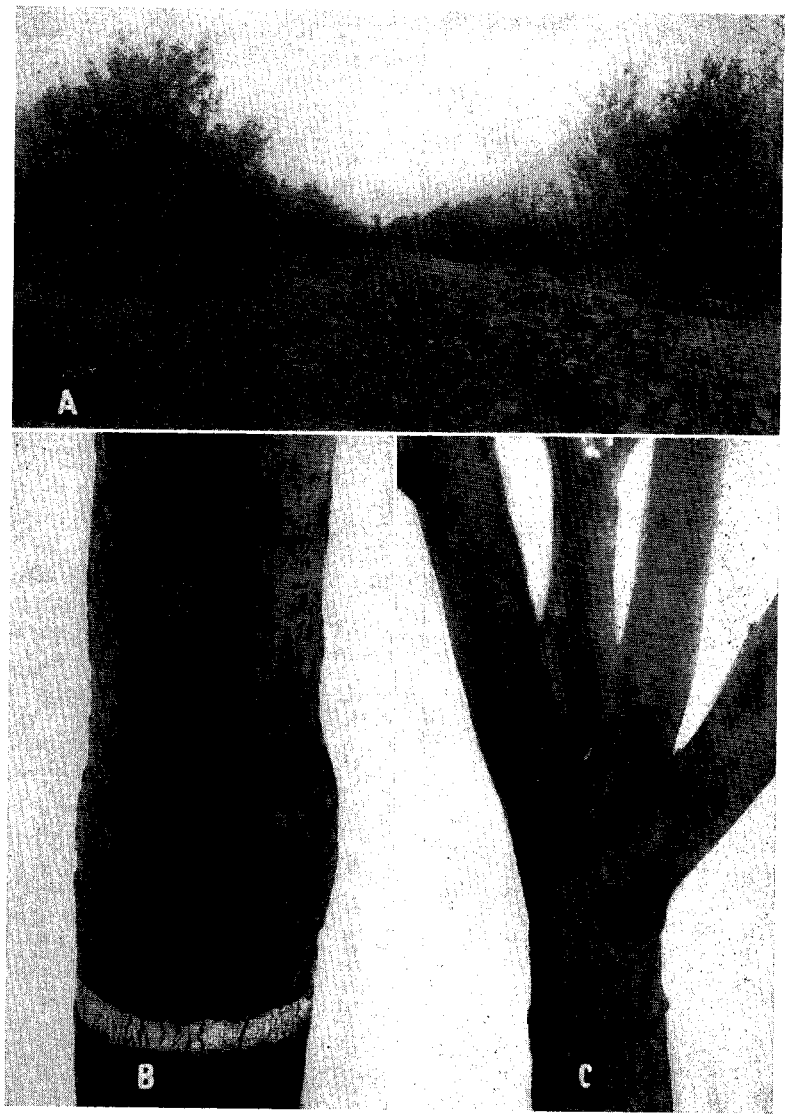

Fig. 7—Effects of November, 1940, freeze. (A) Branch, twig and whole tree injury are shown in this view. On the right are straw mulch trees. (B) Trunk injury. This is a "double-worked" Grimes tree. The intermediate stock survived the freeze. (C) Although the trunk bark on this tree was not killed, the crotch was so badly injured that survival of the tree is doubtful.