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Factors Causing Cull Apples in Missouri

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This bulletin reports the results of a two-year investigation of the causes of cull apples in representative sections of Missouri. For the purpose of this survey, a number of orchards were selected in two commercial apple growing districts of the State. Greene and Lawrence counties constituted the southwest district and Jackson, Lafayette and Buchanan counties comprised the northwest district (Figure 1).

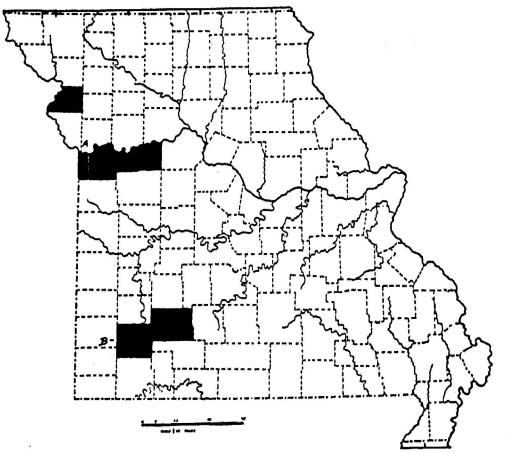

Fig. 1.—Areas in black show regions covered by this study.

The investigation was undertaken with the object of gathering more exact information on the relative importance of the various causes that contribute to the formation of cull apples. Such knowledge should be of value to the fruit growers in their future orchard practices and should lead to more profitable production of apples. The disturbing effect of cull apples in the marketing of this fruit, especially locally, is fully realized by the trade. It is a veritable menace in some years and in certain sections. This is equally true in Missouri as in many other apple producing states. During the past six or seven years, however, there has been a marked improvement in apple production and market-

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ing in our State, resulting in a greater percentage of the total crop being of commercial value, as the following table will show:

THE APPLE CROP IN THE STATE OF MISSOURI

	Total Apple Crop Bus.	Commercial Apple Crop Bus.	% Commercial Was of Total
1926	5,015,000	1,857,000	37.0
1927	2,104,000	870,000	41.3
1928	3,380,000	1,422,000	42.1
1929	2,200,000	1,140,000	51.8
1930	1,560,000	849,000	54.4
1931	5,412,000	2,250,000	41.6

In comparison with other apple-producing regions, this record is by no means flattering. There is ample room for further improvement.

There are many apple growers who do not seem to be fully aware of the fact that the demand for apples is becoming more exacting and discriminating from year to year. Hence, conspicuous differences exist in the price between "good" and "poor" fruit. The production of good apples may be a relatively profitable undertaking; the growing of culls is seldom worthwhile. Fortunately, a large number of the causes of culls in this State are amenable to preventive and control measures, which are within the means and general knowledge of the majority of commercial orchardists. More information on the subject, therefore, should be of value to every apple grower in the State.

METHODS OF SECURING INFORMATION

The work of this survey was conducted by way of personal visits in 1928 and 1929 to representative orchards, which were selected through the cooperation of county agents in the respective districts. Surveys of the best and poorest growers of the counties were not attempted, since it was desired to strike as nearly an average as possible. The same orchards were visited both years during the period the fruit was being picked and graded. The first trip was made in the early part of the harvesting season to study the causes of culls among the early fall varieties. The second trip was timed to reach the districts at the season of major harvesting operations of the late fall and winter sorts. The varieties of apples studied were Jonathan, Grimes, King David, Ben Davis, Ingram, Paynes Late Keeper, Winesap and York.

A representative sample of cull apples from each orchard was examined as to insect and mechanical injuries, fungous diseases and other defects which were responsible for the apples being thrown out as culls in grading. The number of times each disease, insect injury, or physical

defect occurred on the fruits was recorded on small adding machines mounted on a suitable base for convenient use in the orchard or packing house. In many cases two or more, but usually not over three, specific defects were found on one fruit. In such instances all of the defects were recorded. The samples varied from 2 to 25 bushels, depending upon the total crop of each variety and the amount of time the writers could spend in the orchard. The smaller samples were taken from smaller orchards. In a few cases the total quantity of culls present were inspected. In 1928 data were obtained from 20 orchards in the southwest district and from 11 orchards in the northwest district, and in 1929 from 13 and 9 orchards in the respective districts. The total number of apples examined during the two years was close to 100,000.

In order to determine the percentage of culls in the apple crop, information was secured on the relative quantities of No. 1, No. 2, and cull grades of each variety. Data were also obtained on the price received for each variety and grade. And to have a background of the causes leading to the formation of cull apples, the orchards were inspected for such diseases as affect both the tree and the fruit. Notes were kept as to the general condition of the orchard, on methods of cultivation, fertilization, spraying, pruning, the handling of the crop, and the nature of orchard equipment. The ability of the owner or manager gave an indication as to the probable causes of apples to cull out as they did.

Because of the nature of the work done, it was impossible to obtain records from the same number of growers for each variety in both districts or all varieties in the same orchard. Only a limited time was spent in each community. This prevented the obtaining of data on all varieties grown in the same orchard. The most important, such from which really representative cull samples could be obtained, however, were considered in each case. The evidence presented here is thought to give a reasonably accurate cross-section of the major causes of cull apples and of the difficulties involved in the production of more fruit of a high commercial grade.

THE RESULTS

The records secured during the two years while this investigation was in progress are presented in tabular and graphic form under three divisions: (1) the amount of apples in each grade; (2) the prices received for each grade and variety; and (3) the relative importance of various factors responsible for culls. Practically all of the figures are averages and summaries of a large number of individual records. The total number of tables and graphs have been reduced to the lowest number for reasons of brevity and economy. It is hoped that this has made the report also more readable.

Amount of Apples in Each Grade.—Most of the growers whose apples were studied in 1928 used three grades only, namely No. 1, No. 2 and culls. In 1929 several growers made also an "orchard run" or a "commercial pack". Grades No. 1 and No. 2 were used to denote quality usually designated by these grades, and approaching U. S. No. 1 and U. S. utility (No. 2) grading requirements. Culls including all apples which fell below commercial quality. "Orchard run" packs contained all apples as they came from the trees with "rots and knots out". "Commercial pack" was a combination grade of No. 1 and No. 2 apples. It must be stated that the quality designated by these five grades was not uniform, grade for grade, in two districts.

Results for 1928.—Table 1 and Figure 2 show that in 1928, on the average, 62.38 per cent in the southwest and 60.44 per cent in the northwest of the commercial apple crop met the requirement of the grade known as No. 1. Consequently a relatively small portion of this fruit was sold as No. 2, and still less as culls. This shows that 1928 was a very good season for apple growing in Missouri.

The three varieties that graded out best in 1928 in Southwest Missouri were York with 69.10% No. 1 fruit, Ben Davis with 67.75% and Grimes with 66.30% in the same grade. Data on Yorks were secured in three orchards, one of which was exceptionally well cared for. The

TABLE 1.—PERCENTAGE OF FRUIT IN EACH GRADE—1928

Variety	District	No. 1	No. 2	Culls
Grimes	Southwest	66.30	26.66	7.04
	Northwest	63.40	27.80	8.80
Jonathan	Southwest	54.70	27.30	18.00
	Northwest	62.17	24.54	13.29
Ingram	Southwest	64.42	21.43	14.15
	Northwest	-----	-----	-----
Ben Davis	Southwest	67.75	15.26	16.99
	Northwest	54.84	28.35	16.81
York	Southwest	69.10	20.38	10.52
	Northwest	61.66	26.86	11.48
Paynes Late Keeper	Southwest	65.69	22.71	11.60
	Northwest	-----	-----	-----
King David	Southwest	49.26	37.82	12.92
	Northwest	-----	-----	-----
Winesap	Southwest	-----	-----	-----
	Northwest	60.10	25.10	14.80
Average	Southwest	62.38	24.49	13.13
	Northwest	60.44	26.53	13.03

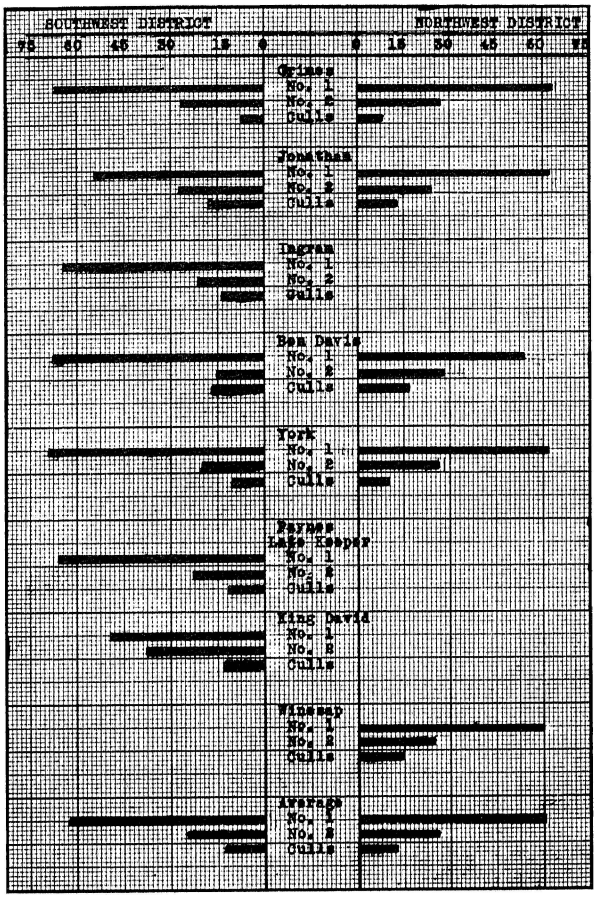


Fig. 2.—Percentage of Apples in Each Grade in 1928.

record on Ben Davis represents an average of 15 orchards and shows a variation of 95.40% number one in one orchard to 100% culls in another. These, of course, are two extremes, conditioned largely by good and poor orchard management. Ben Davis is a tough-skinned variety which can stand considerable rough handling. It is also somewhat easier to grow. Hence, its rank is not surprising. Mechanical injuries and bruises cause a large number of apples to become culls.

The two varieties that graded out best in Northwest Missouri were Grimes and Jonathan with 63.40% and 62.17% No. 1 respectively. Just why these two comparatively soft-fleshed fall varieties should grade out above a variety like York or Winesap is not quite clear. It may

be due to the fact that a considerably higher price is paid for Grimes and Jonathan on the market, as will be shown farther on. The growers of this district can afford to and usually do handle these apples with more care both during the growing and harvesting of the crop. The nearby Kansas City market and the many roadside outlets probably determine the higher price of Grimes and Jonathans.

Probably one of the reasons for Grimes grading out so well was that color is no factor with this variety. In the case of all other varieties the lack of sufficient color was the reason for a large percentage of culls. Information on grading of Grimes was obtained from 15 orchards.

The King David variety shows a greater percentage of No. 2 apples and culls than any of the other varieties. This most likely is due to its relative susceptibility to disease, especially to a physiological trouble known as King David Spot. The growing of this variety has been somewhat discouraged in Southwest Missouri because of this trouble. King David has also a tendency to be undersized and sometimes of poor color.

Results for 1929.—The season of 1929 was unusually bad in Missouri for the growing of quality apples. In the southwest district, particularly, the weather was favorable for the spread of insects and diseases and unfavorable for the application and effectiveness of preventive and control measures. Much rain in the spring was conducive to the spread of apple scab and blotch and made it difficult to maintain an adequate coverage with a protective fungicide. Weather conditions likewise interfered

TABLE 2.—PERCENTAGE OF FRUIT IN EACH GRADE, 1929

Variety	District	No. 1	No. 2	Culls	Orchard run	Commercial pack
Grimes	Southwest	14.99	10.90	37.05	13.08	23.98
	Northwest	51.71	29.56	18.73	-----	-----
Jonathan	Southwest	29.76	30.98	27.30	.43	11.53
	Northwest	52.45	25.47	22.08	-----	-----
Ingram	Southwest	2.00	1.48	72.52	24.00	-----
	Northwest	60.91	20.99	17.39	.71	-----
York	Southwest	39.37	20.04	20.85	19.74	-----
	Northwest	66.92	12.69	6.65	-----	13.74
Ben Davis	Southwest	25.43	31.01	26.41	10.72	6.43
	Northwest	41.44	44.92	13.64	-----	-----
Winesap	Southwest	-----	-----	-----	-----	-----
	Northwest	82.29	6.89	10.82	-----	-----
Black Twig	Southwest	-----	-----	-----	-----	-----
	Northwest	63.41	21.46	15.13	-----	-----
Average	Southwest	21.33	18.19	34.78	13.65	12.05
	Northwest	52.07	21.07	13.63	.60	12.63

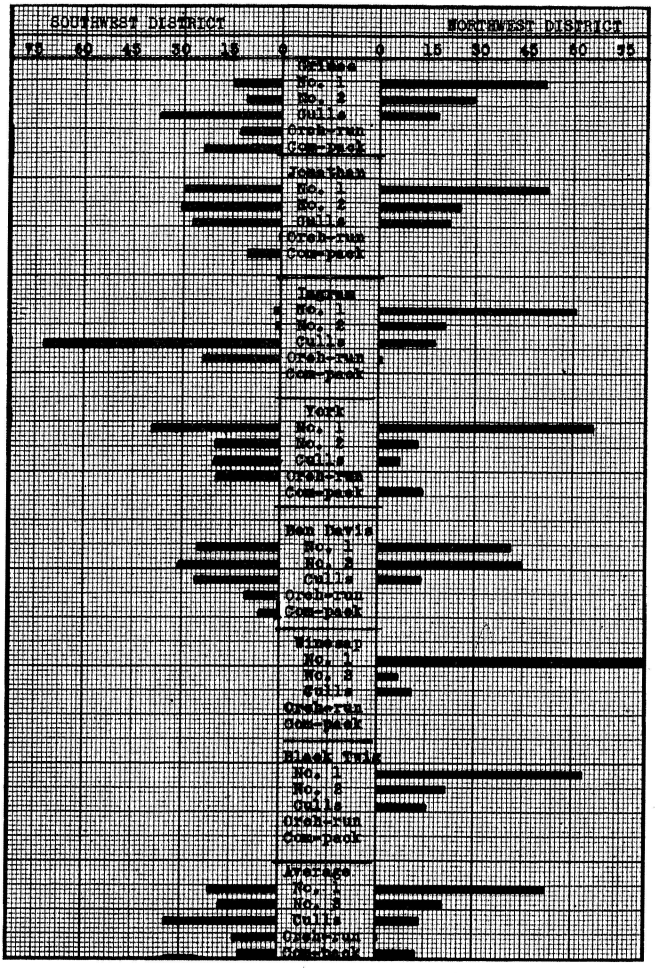


Fig. 3.—Percentage of Apples in Each Grade in 1929.

seriously with the usual spray schedule for the control of codling moth and aggravated other orchard ills to an unusual degree. This is reflected directly in the grades used and the results of grading apples in the southwest part of the State in 1929.

Table 2 and Figure 3 present summaries on how the different varieties graded out in 1929 in the two districts. Of the 1845 bushels of Grimes that passed over the grading tables in the southwest orchards visited, only 14.99% met the requirements of No. 1 grade, while 37.09% were considered culls. In fact, only two of the growers attempted to run a

No. 1 pack of this variety. Grades No. 2, orchard-run, and commercial-pack amounted to 10.90%, 13.08%, and 23.84% respectively. A much better showing was made with the Grimes in the northwest district, where in the orchards visited 51.71% of the fruit met the requirements of No. 1 grade, 29.56% was classified as No. 2 and 18.73% was below commercial quality.

Of the 11,673 bushels of Jonathan apples graded in 12 representative orchards in the southwest part of the State, only 29.76% went into No. 1 grade. Another 42.94%, however, was of commercial quality and was packed for the market as follows: No. 2 grade 30.98%; orchard-run 0.43%; and commercial pack 11.53%. Culls amounted to 27.30%. Just as in the case of Grimes, the showing was much better with Jonathans in the northwest district. Of the 68,400 bushels of Jonathans recorded in this district 52.45% were put in No. 1 grade, the range being from 33.33% to 83.00%. Slightly over half of the remainder graded as No. 2 and the rest found their way to the cull pile.

Only two growers reported the grading of Ingram in the southwest district with a total of 2500 bushels. A mere 2% could be sold as No. 1, while 72.52% fell below commercial grade and were eliminated as culls. In the northwest district, on the contrary, 60.91% of this variety was packed as No. 1, 20.99% as No. 2 and 17.39% as culls. These figures are based on an aggregate crop of 9,650 bushels.

Seven growers reported on the grading of 4,610 bushels of Yorks in the southwest district with 39.37% No. 1, 20.04% No. 2, 20.85% culls, and 19.74% designated as orchard-run. Thus this variety graded out 80% commercial quality in this district. Of 7,610 bushels of Yorks considered in the northwest district, 66.92% were placed in the No. 1 grade, 12.69% in grade No. 2, and 13.74% were put in commercial pack, leaving 6.65% as culls. This was the best showing of any variety in 1929.

Nine growers in the southwest district reported on the grading of Ben Davis, involving a total of 12,257 bushels. Table 2 shows that only 25.43% met the requirements of No. 1 grade, 31.01% were sold as No. 2, 10.72% as orchard run, 6.43% as commercial pack, and 26.41% as culls. This important commercial variety, therefore, graded out only 74.59% of commercial value. It was of much better quality in the northwest district. Of the 42,985 bushels reported, 41.44% were sold as No. 1, 44.92% as No. 2 and 13.64% as culls.

The grading of Winesaps was recorded only from the northwest district by four growers having a total of 1525 bushels, which were of unusually high quality. Of the total, 82.29% was placed in No. 1 grade, 6.89% in No. 2, and 10.82% was sold as culls. Of the 489 bushels of Black Twigs grown in two orchards in the northwest district, 63.41% was sold as No. 1, 21.46% as No. 2, and 15.13% as culls.

Our investigations have made it evident that the cull samples furnished not only a representative cross section of the ills of a particular orchard, but also indicated differences in the standards of quality among the various growers. In many instances the variation was considerable indeed. One reason for this deficiency in standardization of graded apples in the state is a lack of agreement and even a tendency toward individualism among the growers. At present ideals of quality and grading are not those of common consent built upon cooperation and maintained by competitive market requirements.

In numerous instances the market is a local one and not a discriminating one, either, so far as quality is concerned. During the past ten years the "truck trade" as a means of disposing of Missouri apples has grown by leaps and bounds. This movement of large quantities of Missouri apples by truck has developed into an extensive huckster trade for the handling of much fruit of unstandardized quality. The huckster trade has proved also a fruitful means of disposing of large amounts of low grade apples, but it has mitigated against a standard pack and quality production. Many of the growers are general farmers also, and apple production is a secondary matter in the general farming scheme. Such a situation is not conducive to ideals for growing apples of high grade. There are numerous exceptions to this general characterization, but the whole situation of grading Missouri grown apples is a complicated one because of lack of fully standardized packs.

In general, grading of apples is more carefully done and a better pack is put up in the northwest than in the southwest district, since the former supplies a more discriminating market. The apple crops in the northwest district graded out better during the two years than they did in the southwest. A direct comparison of quantities on a percentage basis, grade by grade, in the two districts is impossible, for in the northwest mostly two grades were put up while in the southwest district four grades were used. A critical study of the tabulated records may be found of interest and value.

Prices Received for Various Grades of Apples.—The total apple crop in the State was more or less normal in 1928 but below the average in 1929. Because of this shortage, resulting in better prices, a larger percentage of the crop was thrown on the market in the latter year.

Tables 3 and 4 and Figures 4 and 5 give the average prices received in the two years for each variety and grade for which records were obtained. It will be noted that the average price for all varieties and grades of apples was higher in 1929 than in 1928. It was considerably higher in the northwest than the southwest district. This was true of No. 1 fruit as well as of culls. In years of a relatively short crop (1929), the difference between prices of the poorer grades of fruit, No. 2 grade and culls, seems

TABLE 3.—PRICES RECEIVED FOR APPLES OF DIFFERENT GRADES IN 1928

Variety	District	No. 1 Bu.	No. 2 Bu.	Culls Bu.
Grimes	Southwest	$1.51	$0.85	$0.19
	Northwest	2.12	1.25	0.22
Jonathan	Southwest	1.51	0.67	0.19
	Northwest	1.78	1.17	0.33
Ingram	Southwest	1.17	0.72	0.21
	Northwest	----	----	----
Ben Davis	Southwest	1.09	0.42	0.21
	Northwest	1.27	0.86	0.24
York	Southwest	1.30	0.63	0.12
	Northwest	1.50	1.00	0.28
Paynes Late Keeper	Southwest	1.14	0.56	0.13
	Northwest	----	----	----
King David	Southwest	1.08	0.60	0.17
	Northwest	----	----	----
Winesap	Southwest	----	----	----
	Northwest	1.61	1.10	0.27
Average	Southwest	1.25	0.63	0.17
	Northwest	1.65	1.07	0.27

TABLE 4.—PRICES RECEIVED FOR APPLES OF DIFFERENT GRADES IN 1929

Variety	District	No. 1 Bu.	No. 2 Bu.	Culls Bu.	Orchard run Bu.	Commercial pack Bu.
Grimes	Southwest	$1.21	$1.08	$0.35	$----	$1.44
	Northwest	2.37	1.45	0.45	----	----
Jonathan	Southwest	1.34	1.01	0.47	----	1.25
	Northwest	2.03	1.47	0.37	----	----
Ben Davis	Southwest	1.42	0.99	0.34	0.79	1.28
	Northwest	1.49	1.01	0.43	----	----
Ingram	Southwest	----	----	----	----	----
	Northwest	2.21	----	0.38	----	----
York	Southwest	----	----	----	----	----
	Northwest	1.64	1.25	0.33	----	1.75
Winesap	Southwest	----	----	----	----	----
	Northwest	1.82	1.21	0.39	----	----
Average	Southwest	1.36	1.03	0.38	----	1.33
	Northwest	2.00	1.28	0.39	----	----

to be smaller than in years of an abundant crop. There was, likewise, a very slight difference in price for the lower grades in the two districts for 1929.

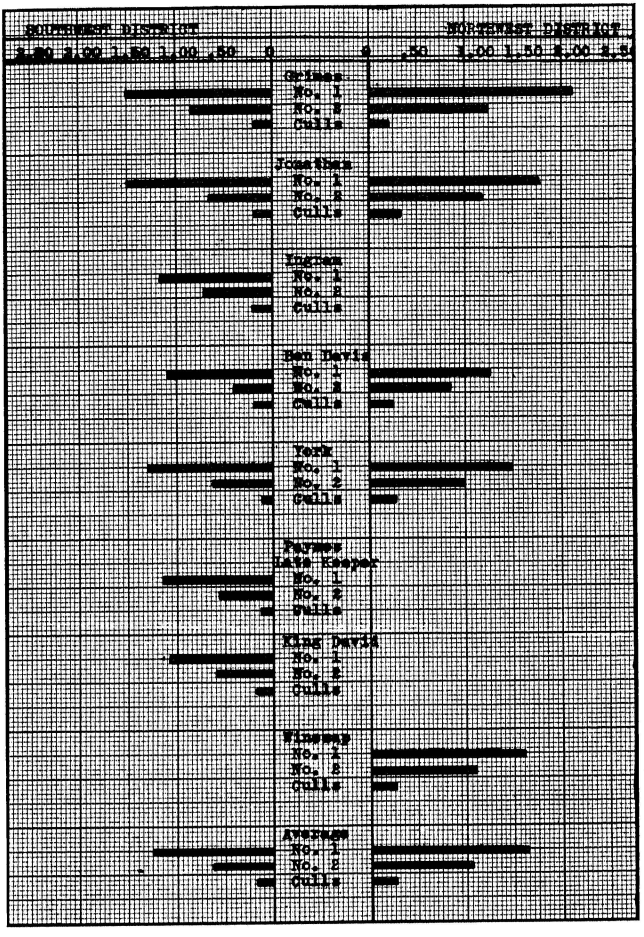


Fig. 4.—Prices per Bushel Received for Apples of Different Grades, 1928.

The highest average prices received for apples in the northwest district cannot be accounted for wholly on the basis of quality alone. A large number of factors enter into the problem of "price getting". The cumulative effect of quality production in the northwest district is usually reflected in better prices. This apple producing region of Missouri is located near two important markets, Kansas City and St. Joseph. The district supplies a somewhat more discriminating trade, where a premium on quality is emphasized. This stimulates ideals in the production of high quality fruit, and in turn makes for better insect and disease control, more efficient orchard practices, and a more standardized grading of the crop.

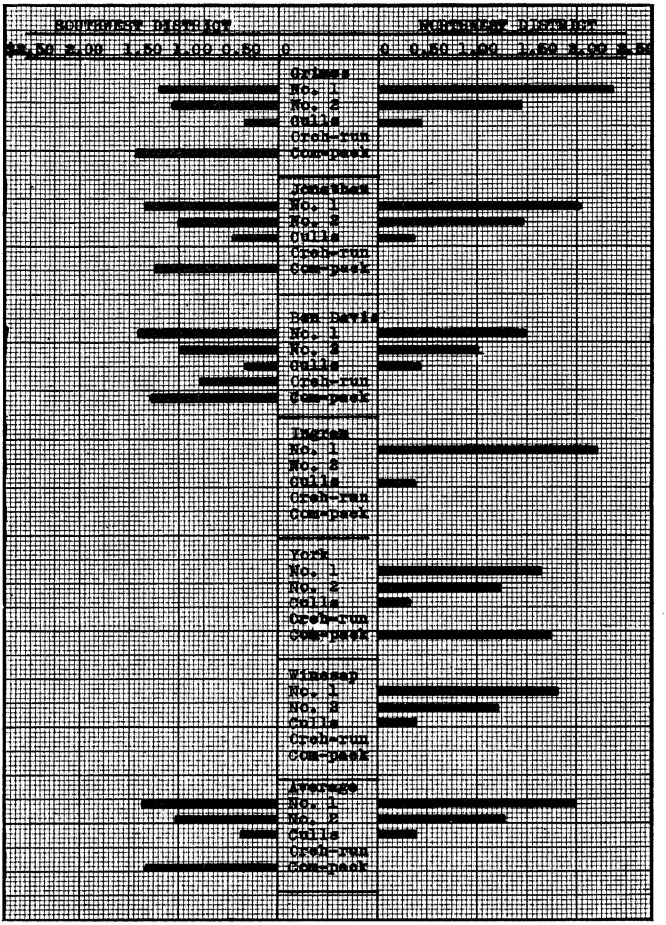


Fig. 5.—Prices per Bushel Received for Apples of Different Grades, 1929.

The average price per bushel of No. 1 apples in the southwest district was $1.25 and $1.36 respectively for the two years, and in the northwest district $1.65 and $2.00. No. 2 apples were sold during the two years at an average price of $0.63 and $1.03 per bushel in the southwest district and at $1.07 and $1.28 in the northwest. Culls were disposed of at 17 cents and 38 cents per bushel in 1928 and at 27 cents and 39 cents in 1929 in the two districts.

Of the more popular varieties Grimes and Jonathan sold for the highest prices in the northwest. These two varieties commanded also a relatively high price in the southwest, both in No. 1 and so-called "com-

mercial pack". Yorks, Winesaps and Ingrams were sold remuneratively when properly graded, while Ben Davis, King David and Paynes Late Keeper were priced at a somewhat lower figure, going a little above one dollar per bushel in 1928 for No. 1 stuff, although some Ben Davis brought as high as $1.40 in 1929.

That in 1929 No. 1 Grimes sold for less per bushel in the southwest district than No. 1 Ben Davis may be due to the difficulties involved in bringing the Grimes through to maturity under extremely adverse weather conditions in that year. The fruits dropped badly early in the season and in many cases were harvested prematurely and ripened under open sheds. These so-called No. 1 Grimes were rushed to the market for fear of storage troubles, and a lower price was accepted than the actual quality of the fruit would otherwise command. Much of the crop of Grimes in the Northwest district was placed in the cold storage and sold when more favorable prices could be procured. These facts touching on the sale of Grimes in the two districts hold equally true for the Jonathans in 1929. It will be noted that practically the same price per bushel for Ben Davis was received in both districts.

The limited amount of data respecting the selling of the apple crop of 1929 emphasizes the difficulties of marketing Missouri's apples grown under such unfavorable seasonal conditions of weather. Much of that portion of the crop that was stored did not move out in time to be included in this survey.

Our apple price studies in a large number of orchards indicated that the growers who received the highest prices for No. 1 fruit also received more for No. 2 and culls. Orchardists who received the most per bushel were in general the ones who were best known to the buyers by the quality of their No. 1 pack. Thus the higher prices reflect back upon the efficiency of the grower. Apple producers in Northwest Missouri received on the average more per bushel because they were closer to the larger markets and frequently were selling apples from a roadside stand.

It seems to be the opinion of some orchardists in the State that the more apples grown per tree or acre the better. "The more the better" is all right provided most of the fruits are of such quality that they can be sold at a profit above production costs. The writers realize, of course, that in some years or in some orchards it is impossible and unprofitable to grow a crop with a large percentage of No. 1 apples. In such years it would not be economical to try to grade certain varieties too closely. The amount of first-class apples in such cases would not be enough to pay for the labor of sorting the fruit and the grower would make more money by selling the entire crop as inferior fruit. But in most years and with most varieties, it will be more profitable to grow apples of such

quality that a first class pack can be made. The figures of this investigation show that this kind of fruit brings the largest returns to the grower.

The average price received for cull apples seldom exceeds 50 cents per bushel, but most frequently large quantities of culls are sold for next to nothing. Some orchardists do not seem to realize how much it actually costs to grow such inferior fruit. Then, too, more labor is required in the sorting and grading process when culls are in excess.

CAUSES OF CULL APPLES

All the direct causes of cull apples disclosed by the surveys of 1928 and 1929 are grouped under seven headings and under each the different causes are arranged in the order of importance from the standpoint of injury done. This information will be found in Tables 5 and 6 and Figures 6 and 7. A more detailed picture of the causes of cull apples among the different varieties is presented in Tables 7 and 8. This information is for the year 1928 only, which, of the two, was by far a more normal and average year. A summary showing the relative importance

TABLE 5.—CAUSES OF CULL APPLES IN PERCENTAGES OF THE TOTAL CULL SAMPLES EXAMINED IN 1928

Direct Causes	Southwest	Northwest
1. Lack of size	16.87	19.31
2. Lack of color	8.63	14.16
3. Disease injury:		
Scab	10.18	1.04
Cedar rust	6.89	----
Blotch	4.55	2.12
Bitter rot	3.07	2.78
King David spot	1.82	----
Rots (other than Bitter rot)	.85	----
Jonathan spot	.40	----
Other diseases	.66	.71
Total	28.42	6.65
4. Insect Injury:		
Codling moth	8.93	6.87
Curculio	5.66	6.43
Aphids	3.09	.45
Lesser apple worm	3.00	.50
San Jose scale	----	.94
Other insects	1.56	4.50
Total	22.24	19.69
5. Weather Injury:		
Sun scald	2.11	----
Frost injury	2.07	1.57
Hail	.01	7.08
Total	4.19	8.65
6. Physical Injury:		
Mechanical injury	8.66	14.59
Limb rub	7.18	14.53
Total	15.84	29.13
7. Spray Injury	3.81	2.42

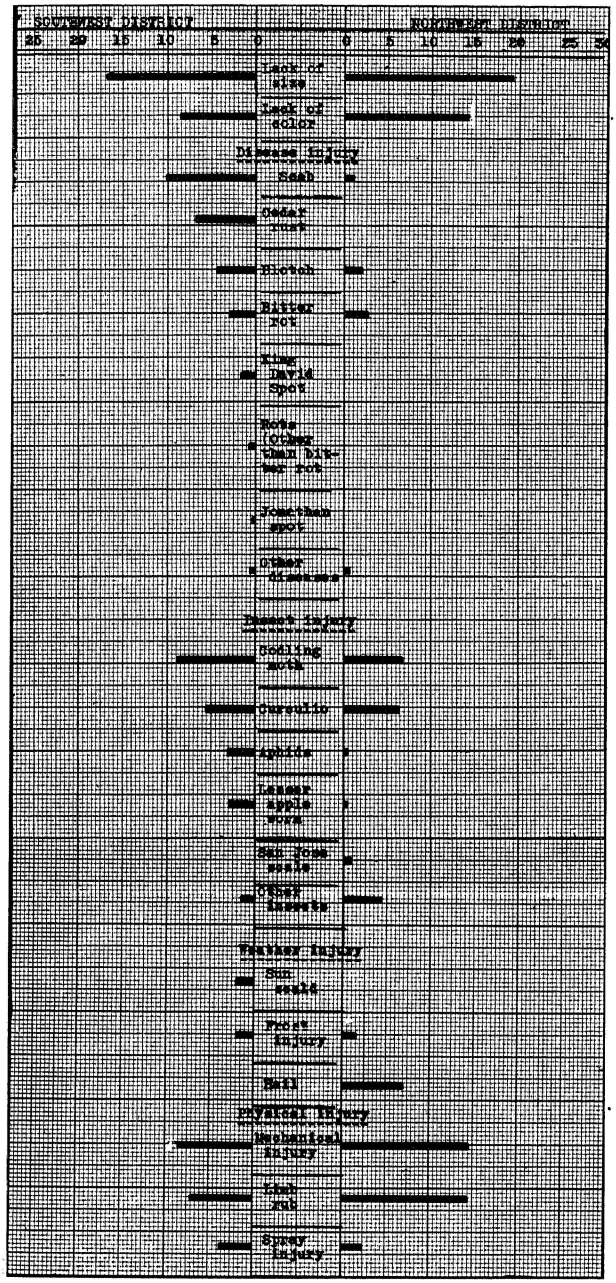


Fig. 6.—Causes of Culls, in Percentages of Total Cull Samples Examined, 1928.

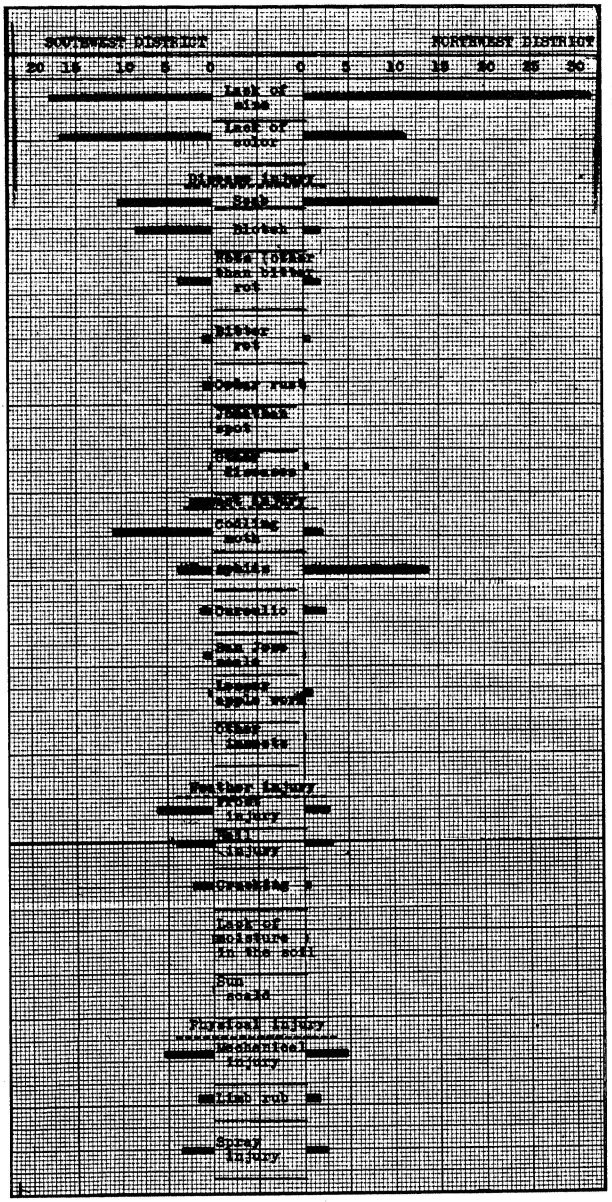


Fig. 7.—Causes of Culls, in Percentages of Total Cull Samples Examined, 1929.

TABLE 6.—CAUSES OF CULL APPLES IN PERCENTAGES OF TOTAL CULL SAMPLES EXAMINED IN 1929

Direct Causes	Southwest	Northwest
1. Lack of size	17.91	31.76
2. Lack of color	16.70	12.26
3. Disease injury:		
Scab	10.33	15.06
Blotch	8.47	1.80
Rots (other than Bitter rot)	3.73	1.88
Bitter rot	1.05	.68
Cedar rust	.79	.24
Jonathan spot	.07	----
Other diseases	.26	.56
Total	24.70	20.22
4. Insect injury:		
Codling moth	10.95	2.22
Aphids	3.73	14.00
Curculio	1.17	2.55
San Jose scale	.82	.05
Lesser apple worm	.37	1.07
Other insects	.11	.09
Total	17.15	19.98
5. Weather injury:		
Frost injury	6.07	2.86
Hail	4.16	3.19
Cracking	2.21	.61
Lack of soil moisture	.18	.16
Sun scald	.18	----
Total	12.80	6.82
6. Physical injury:		
Mechanical injury	5.31	4.77
Limb rub	1.72	1.63
Total	7.03	6.40
7. Spray injury	3.71	2.56

TABLE 7.—CAUSES OF CULL APPLES AMONG DIFFERENT VARIETIES IN SOUTHWEST MISSOURI—1928. IN PERCENTAGES OF TOTAL CULLS

	Grimes	Jonathan	York	Ben Davis	Ingram	Paynes Late Keeper	King David	Average
Lack of size	12.54	9.52	22.23	20.92	25.30	13.52	14.02	16.87
Scab	12.13	8.83	18.69	9.15	4.99	10.45	7.04	10.18
Codling moth	13.11	12.10	6.93	5.40	7.22	8.56	9.18	8.93
Mechanical injury	9.71	8.23	8.42	8.66	18.40	3.08	4.10	8.66
Lack of color	----	19.43	3.50	9.60	10.02	7.06	10.78	8.63
Limb rub	6.96	4.17	11.45	5.47	6.71	10.65	4.83	7.18
Cedar rust	6.15	9.72	6.19	3.15	3.66	10.35	9.06	6.89
Curculio	6.60	5.26	2.45	6.70	4.13	6.57	7.90	5.66
Blotch	3.25	4.07	.49	2.28	9.79	10.75	1.26	4.55
Spray injury	11.32	2.58	4.19	1.97	1.27	1.69	3.65	3.81
Aphids	2.61	1.39	3.19	1.60	1.94	8.36	2.55	3.09
Bitter rot	5.27	3.08	3.77	3.72	----	.70	4.99	3.07
Lesser apple worm	5.60	4.07	2.45	4.59	1.54	.40	2.37	3.00
Frost injury	----	----	.09	14.38	----	----	----	2.07
Sun scald	3.36	1.88	3.93	1.42	.65	1.49	2.01	2.11
Stings	----	----	.63	.62	1.08	5.87	2.72	1.56
Dry Rot	1.01	2.19	----	----	2.72	----	----	.85
Hail injury	----	.10	----	----	----	----	----	.01
Jonathan spot	----	2.78	----	----	----	----	----	.40
King David spot	----	----	----	----	----	----	12.73	1.82
Other defects	.38	.60	1.40	.37	.58	.50	.81	.66
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 8.—CAUSES OF CULL APPLES AMONG DIFFERENT VARIETIES IN NORTHWEST MISSOURI—1928. IN PERCENTAGES OF TOTAL CULLS

	Grimes	Jonathan	York	Ben Davis	Winesap	Average
Lack of size	28.47	10.73	19.54	12.03	25.76	19.31
Mechanical injury	12.65	14.87	15.31	15.77	14.32	14.59
Limb rub	17.47	18.14	14.54	11.48	11.04	14.53
Lack of color	----	21.40	10.54	15.58	23.28	14.16
Hail injury	15.67	7.28	5.37	4.85	2.20	7.08
Codling moth	3.99	10.45	8.04	6.02	5.87	6.87
Curculio	5.96	7.98	8.81	4.02	5.36	6.43
Stings	2.05	----	9.43	6.87	4.15	4.50
Bitter rot	5.67	4.12	.35	2.65	1.11	2.78
Spray injury	3.89	.42	3.93	2.03	1.85	2.42
Blotch	.13	1.39	1.40	6.09	1.61	2.12
Frost injury	----	----	----	7.87	----	1.57
Scab	1.34	1.06	----	2.80	----	1.04
San Jose Scale	----	----	1.82	----	2.88	.94
Lesser apple worm	1.04	.95	----	.49	----	.50
Aphids	1.17	.05	----	1.03	----	.45
Other defects	.50	1.16	.92	.42	.57	.71
Total	100.00	100.00	100.00	100.00	100.00	100.00

of the various causes responsible for the formation of cull apples in both the southwest and northwest apple growing districts of Missouri will be found in Tables 9 and 10 and Figures 8 and 9.

TABLE 9.—PERCENTAGES OF CULL APPLES GRADED OUT IN 1928 BECAUSE OF:

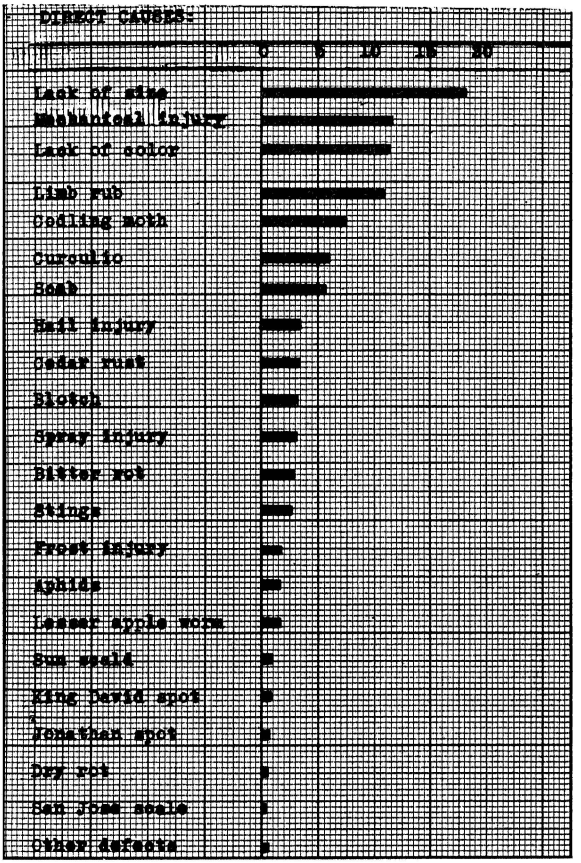
Lack of size	18.11%	Bitter rot	2.93%
Mechanical injury	11.61	Stings	2.77
Lack of color	11.42	Frost injury	1.81
Limb rub	10.88	Aphids	1.77
Codling moth	7.50	Lesser apple worm	1.73
Curculio	6.06	Sun scald	.98
Scab	5.65	King David spot	.91
Hail injury	3.54	Jonathan spot	.66
Cedar rust	3.46	Dry rot	.62
Blotch	3.34	San Jose Scale	.46
Spray injury	3.11	Other defects	.68

TABLE 10.—PERCENTAGES OF CULL APPLES GRADED OUT IN 1929 BECAUSE OF:

Lack of size	24.35%	Curculio	1.81
Lack of color	14.66	Limb rub	1.68
Scab	12.56	Cracking	1.47
Aphids	8.52	Bitter rot	.88
Codling moth	6.89	Lesser apple worm	.70
Blotch	5.36	Cedar rust	.53
Mechanical injury	5.05	San Jose scale	.46
Frost injury	4.58	Lack of moisture in the soil	.17
Hail injury	3.71	Sun scald on the fruit	.09
Spray injury	3.17	Jonathan spot	.04
Rots (other than Bitter rot)	2.87	Other defects	.45

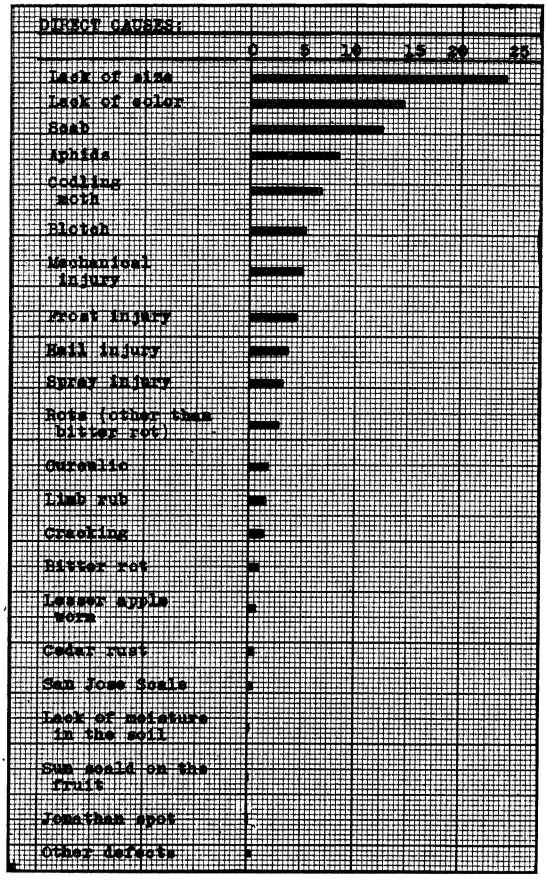
Of the many causal factors of cull apples, some are of distinctly greater importance, while others are of minor consequence. Of the seven

Fig. 8.—Percentage of Culls Graded Out in 1928 Because of:



most important ones, which were responsible for the production of two-thirds to three-fourths of the culls in 1928 and 1929, five appeared in both years. These are lack of size, lack of color, scab, codling moth, and mechanical injury. Limb rub and curculio caused a large percentage of culls in 1928; aphids and blotch injured badly many fruits in 1929. Thus some of the more important troubles are present every year while others may be serious in some seasons and less so in others, depending mainly upon the weather.

Fig. 9.—Percentage of Culls Graded Out in 1929 Because of:



Lack of Size.—Insufficient size was the one factor which caused more apples to be thrown out as culls than any other single factor found in both districts and both years. Of all the culls inspected, 10 to 30% of the fruit, depending upon variety and orchard, were thrown out of commercial grade due to small size. More apples were culled out because of size in the northwest than in the southwest district. Two reasons may be assigned for the elimination of a large percentage of apples in the northwest district because of this deficiency. The grading is done more carefully and strictly in this section and aphid injury, which leads to misforming and stunting of the fruit, was very serious in the northwest district in 1929.

It is rather surprising that such a high percentage of culls should be caused by a factor like lack of size, since it may be prevented to a large extent by four major orchard practices, namely: cultivation and cover crops, fertilization, pruning and thinning. A tree which can obtain only enough food material from the soil to sustain life and produce weak growth cannot grow and mature apples of normal size for the variety. Often cultivation or a nitrogen fertilizer will invigorate such trees, produce more and better foliage, and improve the size of the apples. A tree with fine green leaves, as a rule, will yield more and better apples than one having a sparse yellowish foliage. Size in apples can be increased also by judicious pruning, but particularly so by fruit thinning. It is the opinion of the writers that systematic thinning should be established as a regular practice in heavy crop years in many of the orchards that were studied. Few, if any, practices will so directly increase the size, grade and quality of fruit as thinning. By reducing the number of defective specimens early in the season, it will decrease the cost of handling the crop. Proper thinning would do away with a large part of the cull pile.

Lack of Color.—In point of importance, lack of color was the second major cause of defective apples, averaging 12% of the total quantity of culls. On the average, more Jonathans were discarded because of poor color than any other variety. In 1929 meteorological conditions in particular were responsible for the lack of proper coloring of this and other varieties, especially in the southwest district. Other contributing causes were faulty pruning and lack of thinning the fruit. Practically all of the poorly colored specimens were produced in the interior of the tree where there is less light to color the fruit.

Apple Scab.—Of the 20 to 30% of culls caused by various diseases, scab was by far the most important trouble, accounting for half of the diseased specimens. Although in 1928 only 1% of the culls in the northwest were infected with scab, it was especially destructive in 1929, due to rainy and cool weather in the spring. The cool and moist atmosphere was favorable to the development of this disease and interfered with the timely application of fungicidal sprays; hence, many growers failed to get the usual control. Timeliness and thoroughness in spraying, with emphasis on "timeliness", are essential factors in the method of combating scab. It had a special significance in the 1929 season.

Apple Blotch.—Apple blotch is primarily a disease of the southern portion of the state where it is far more destructive than in the north. From 5 to 8% of all the culls were caused by blotch in the southwest district, but it was far less serious in the northwest. Because of the weather, this disease, too, was more prevalent in 1929 than in the previous year. While spraying is essential for the control of blotch, carefu

pruning will remove a large percentage of the cankered twigs and thereby reduce the spread of this disease.

Cedar Rust.—Serious injury from cedar rust was found only in 1928 and in the southwest district. The alternate host of this disease, the red cedar, is more common in the southern portion of the State; hence the greater prevalence of cedar rust there. Under favorable weather conditions, it can be an obnoxious pest of the apple.

Various Rots.—The various rots encountered on cull apples were as a rule more prevalent in the southwest than the northwest district and more in 1929 than in 1928. Bitter rot was found more frequently than any of the other common forms, such as dry rot, brown rot, and black rot, which are not designated separately in the tables but given as "rots (other than bitter rot)". Most of the rots were associated with wounds previously made by codling moth larvae, curculio, and various mechanical injuries and cracks, where the protective covering of the apple had been broken. Many rotted apples, of course, are left unharvested, particularly when they had dropped from the tree.

Other Disease Injury.—King David and Jonathan spots, which are present on and characteristic of these varieties, only caused in 1928 up to 2% of the total culls. Naturally on these two varieties the spot was much more serious than that (Table 7). There is no known specific remedy for these troubles. A small amount of culls, usually less than 1%, was caused by other unidentified diseases.

Codling Moth.—Although the total insect injuries in the two districts was practically the same during the two years under investigation, there was a great variation in the extent of destruction of fruit by the various kinds of insects in the southwest as compared to the northwest district. As was to be expected, codling moth did more damage than any other insect, particularly so in South Missouri where, in either year, it accounted for approximately 10% of all culls. The greater codling moth injury there must be expected because of the weather, which was favorable for a heavy second brood of moths and a partial development of a third brood. The injury from this insect in most cases was caused from a late brood, which seemed to indicate that the growers stopped spraying a little too soon. There was a heavy spread of infestation in the southwest district from neglected home orchards to the commercial plantings, which is a handicap in the control of this pest. A shorter growing season and better sanitary conditions made for more efficient codling moth control in the northwest district, where in 1929 a remarkably small percentage (2.22%) of culls were caused by this insect.

Curculio.—Injuries to apples by curculio were largely through feeding punctures. In most cases the punctures had been made when the apples were small and showed a large depression when the fruit

was fully grown. Since many curculio injured apples drop when young, the amount of punctures found on mature fruit does not give an accurate idea of the real extent and seriousness of this insect. In the two districts, curculio injuries accounted for 5.66 and 6.43% of culls in 1928 but only for 1.17% and 2.55% in 1929. In both years this insect seems to have done somewhat more damage in the northwest than in the southwest district. Curculio appears to be one of the most difficult insects to control. Of the several practices, proper spraying is the most effective one.

Aphids.—In both years about 3% of the apple culls in the southwest district were due to aphid injury. Of the three kinds usually present in Missouri orchards, the Rosy apple aphids are most frequently responsible for the production of small, gnarly and puckered apples.

It is very possible that the greater injury to apples by aphids is not the actual percentage of aphisized apples that the orchard contains, but the injury to the trees themselves. They lower the vitality of the tree so that all the apples are of smaller size than they would be under normal circumstances. This pest was found in certain sections of some orchards while others were practically free from it.

The number of apples injured by aphids in 1928 in the northwest section was insignificant, but it was terrific there in 1929, accounting for 14% of all the culls. A number of growers did not spray for control of aphids. They often reason that the cost of the nicotine and its application is not justified. This line of reasoning evidently did not hold good in 1929, if it ever does.

Lesser Apple Worm.—The lesser apple worm was not a serious pest in either district. It did cause, however, about 3% of culls in the southwest in 1928. The typical injury of the insect is conspicuous and unsightly, thus forcing an apple out of grade, which might be in all other respects of commercial quality. With thorough spraying, control of this insect should not be difficult.

San Jose Scale.—Only a very small fraction of the apple culls under investigation were infested with this scale and it was found only in a few orchards. The insect was present in two of the best kept orchards included in the survey. The worst infestation was noted in an orchard in which peach trees had been planted as fillers. The insidious attack of this scale and its power of rapid multiplication indicate a possibility of injury which the apple growers of Missouri cannot ignore for a single season.

Weather Injury.—Culls caused by frost and hail injuries or by sun scald, cracking, or lack of moisture in soil (1929) are grouped under this heading. It will be noted in Tables 5 and 6 that from 4 to about 13 per cent of culls were due to weather injury in the two districts and for the two years.

Frost injuries were found in varying degrees among the several varieties of apples as disclosed by the examination of numerous cull samples, along with other causes of russeting often found on the same specimen. It was exceedingly difficult and often impossible to determine the extent of frost injury in many instances. A rather arbitrary differentiation from other forms of russeting was established. When the russet on the apple appeared as a solid band, so-called "frost band", and was accompanied by rough brown areas on the skin of the fruit, causing marked disfiguration and often malformation, the injury was ascribed to frost. Other russeting not ascribed to spray injury, and not recognized directly as frost injury, was included under frost injury when found on the same specimens. Frost injury was comparatively slight in 1928 but was the cause of 6.07 per cent of culls in the southwest and 2.86 per cent in the northwest district in the 1929 season.

Hail injury was quite variable from orchard to orchard. It caused a considerable loss—7.08% of all culls—in Northwest Missouri in 1928, while in 1929, 4.16% of the culls in the southwest and 3.19% in the northwest district showed this blemish.

Cracking, noted in 1929 only, was confined almost entirely to the York variety. It was prevalent mainly in the southern area.

Sun scald on fruit accounted for a small percentage of culls. Like many other troubles, it, too, was confined mainly to the southern area.

Little really can be done to prevent any of the above types of weather injuries. But, after all, in comparison to other causes of culls, injuries from frost, hail, cracking or sun scald were not serious in the two seasons when the investigation was made.

Mechanical Injury.—Any injury where the skin of the apple had been freshly broken or the fruit was bruised was called mechanical injury. It includes, therefore, all physical injuries incidental to harvesting operations, transportation to the packing shed or the grading table, and handling in packing. It was found that the amount of mechanical injury varied directly with the method of harvesting and the type of pickers and packers. It accounted for about 5% of all culls in 1928 and up to 15% in 1929. This is an unusually high and unnecessary loss, especially when we consider the fact that a majority of the fruits thrown out of commercial grade because of mechanical injury were of No. 1 quality in all other respects.

Mechanical injury is one of the causes for defective apples which is too common in commercial orchard operations in Missouri and one largely under the control of the grower and packer. A great deal of mechanical injury to apples at harvest time could be eliminated by using the right kind of containers and a more experienced and careful

harvesting crew. As a general rule, the growers could well afford to spend more time and thought on the method of harvesting the crop, for the financial success of a commercial apple orchard depends largely upon the method used in picking, packing and disposal of the crop. Some very fine apples may be half ruined during the picking and packing operations.

Limb Rub.—In 1928 limb rub caused 14.53% of culls in the northwest and 8.66% in the southwest district. This trouble was comparatively slight in 1929. It was stated by several growers in Northwest Missouri that 1928 was an exceptionally stormy season. Judicious pruning may help by placing the limbs further apart, but, on the other hand, under such conditions, there will be less support to the limbs and they will be swayed farther by the wind.

Spray Injury.—Spray injury was responsible for about 2.5 to almost 4% of the culls in the two seasons, being slightly worse in the southwest district. The greater number of sprays applied and the higher temperature in that part of the state would tend to intensify this trouble. Jonathan, Grimes, King David, York, and Ben Davis seem to be most susceptible to spray injury. There is a tendency now to use weaker spray solutions but to put on additional applications. More careful preparation of sprays will lessen spray injury on apples.

DISCUSSION AND CONCLUSION

It is reasonable to believe that many orchardists in Missouri have an ideal in apple production toward which they strive. This ideal is probably, in many instances, the production of fruit of No. 1 grade. Actually this is impossible, for one can only approach this ideal, but seldom attain it. There are many factors over which the orchardist has no control. And even if he could influence all factors leading to perfect apple production, at least some men would not exert themselves too much. From the data collected in this study, many of the farmers did not control as well as they might have done the few factors which were within their power to remove or modify. On the other hand, some growers approached the ideal very closely. Number one apples ran as high as 90% of the total crop, with only 2% of culls. This, of course, is the extreme and only the growers' exceptional ability, combined with a very favorable season, could accomplish it. According to our investigations, it may be expected that at least 60% of the total crop should be of No. 1 grade. A number of varieties graded out above this figure in 1928.

Many growers did not obtain an average of 60% of No. 1 apples. Practically all of these growers were general farmers. This seems to be one of the main reasons for the crops to cull out as low as they did. These men are primarily interested in farming and in orcharding only so far as it fits in with their system of farming and to have some fruit for

home use. A large part of their surplus apples were sold to other farmers in the community. The remainder was disposed of on the local market. This type of orcharding does not improve the apple growing situation and actually may be detrimental to it. In the first place, the average farmer is not interested enough and does not try to raise the largest amount of really good fruit. Secondly, he is usually too busy with other farm work just at the time when the orchard needs most of his attention. In all cases, these orchards did not receive as many applications of spray as the commercial orchards and were not pruned or fertilized as well.

From a study of this kind, it is possible to tell the apple growers who are making a profit from those who are not receiving returns enough to pay their expenses. Those who are making orcharding profitable are usually the ones who are in the closest contact with the newer developments in pruning, fruit thinning, spraying and harvesting the crop, and are in touch with the Horticultural Department of the University of Missouri. Growers who are not making enough from their orchards to make the effort worth while are usually the ones who pay little attention to modern developments. Theirs is a continuous story of "hard luck." For the most part they have little to do with their county agent or the Missouri College of Agriculture.

The factors causing cull apples varied greatly with the individual growers and in the different communities of the same section. But the most important factors for a particular section were usually most prevalent in all orchards of the section. For example, lack of color of Jonathans in Southwest Missouri caused more culls than any other factor in all orchards of that section in 1928. This general statement could be made of almost any of the causal factors responsible for culls. It should be the aim of the grower to more nearly control those factors in his orchard which cause the greatest amount of culls. In most cases, unfortunately, this cannot be accomplished, since these factors may be due to conditions over which he has no control. Most farmers, but fruit growers in particular, have to gamble with the weather practically every year.

This survey has made it quite plain that many of the culls studied could be avoided by proper orchard management and greater care exercised in harvesting the crop. The least number of times the fruit is handled, from picking to packing, the fewer culls will result from this source. Frequently enough, a perfectly fine crop of apples may be badly damaged by injudicious and extremely rough handling. The full effect of the injuries may not appear until some period of storage of the fruit and, therefore, may not be seen by the grower. Little can be done to decrease the cost of cultural practices and of spraying and still get good

control of insects and diseases. These costs are more or less constant from year to year, regardless of the size of the crop.

SUMMARY

1. Causes of defective apples were determined by the examination in 1928 and 1929 of over 100,000 specimens of culls in representative orchards in the southwest and northwest apple growing districts of Missouri.

2. The causes of low grade apples, listed in order of decreasing importance, were in *1928*: Lack of size, mechanical injury, lack of color, limb rub, codling moth, curculio, scab, hail injury, cedar rust, blotch, spray injury, bitter rot, stings, frost injury, aphids, lesser apple worm, sunscald, and others of minor consequence. In *1929*: Lack of size, lack of color, scab, aphids, codling moth, blotch, mechanical injury, frost injury, hail injury, spray injury, rots, curculio, limb rub, cracking, bitter rot, lesser apple worm, cedar rust, and others.

3. The lack of size caused more low grade apples in both apple growing districts and in both years than any other single factor. Insufficient color and mechanical injury were two physical factors of major importance. Of insects, codling moth, curculio and aphids caused the largest percentage of culls, while scab, blotch and cedar rust were the most destructive diseases on the apple fruit. The relative harm done by certain diseases and insect pests varies, from season to season, depending primarily on the weather. In some years, frost and hail reduces a considerable percentage of apples to the state of culls. Spray injury is usually more severe in the southwest than the northwest part of the state.

4. In 1928, most varieties of apples graded out somewhat better in the southwest than the northwest, but in 1929 the fruit was of far better quality in the northwest. The average percentages of apples in each grade were as follows: *1928*, Southwest Missouri—No. 1, 62.38%; No. 2, 24.49%; culls, 13.13%. Northwest Missouri—No. 1, 60.44%; No. 2, 26.53%; culls, 13.03%. *1929*, Southwest Missouri—No. 1, 21.33%; No. 2, 18.19%; culls, 34.78%; orchard-run, 13.65% and commercial pack, 12.05%. Northwest Missouri, No. 1, 52.07%; No. 2, 21.07%; culls 13.63%; orchard run, .60% and commercial pack, 12.63%.

5. In both years, a higher price was received for all grades of apples in the northwest district. This difference in value for No. 1 fruit was 40 cents per bushel in 1928 and 64 cents in 1929. Prices received for the lower grades and for culls varied much less. In general, the best prices were obtained for Grimes and Jonathans.

6. Brief suggestions are given on how to avoid most of the major defects which cause apples to be graded out as culls.

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