Apples

WYE COLLEGE
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Ten Years' Yields of Apples and Pears

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Ten Years' Yields of Apples and Pears

Movements in fruit yields between 1948 and 1957 on a sample of farms in Kent, and their implications for the future of the industry.

Copies of this Report may be obtained, price 5s post free, from: The Secretary, Department of Agricultural Economics, Wye College, Ashford, Kent.

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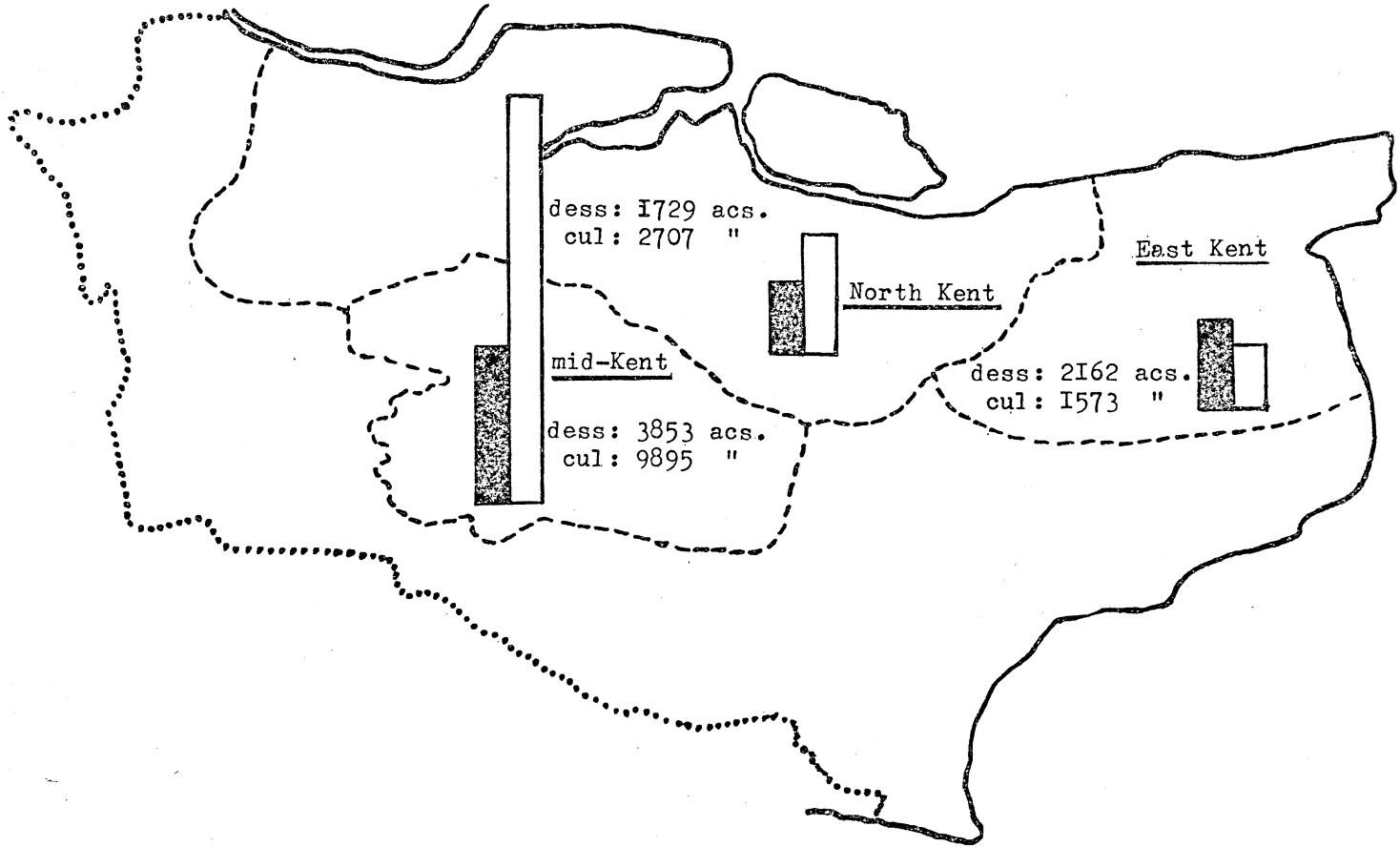
IMPORTANCE OF FRUIT GROWING AREAS, 1951 (Acreages of trees 7 years or older).



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SUMMARY

Kentish fruit growing is in the middle of a change from culinary apple production to dessert apple production: by 1957 more acres were planted with dessert apples than with culinary apples. A look back at the recorded yields of mature trees may provide some pointers to the experience awaiting fruit growers in the future.

The ten-year period concerned, 1948-57, was notable for the virtual absence of frost damage to fruit crops. Summarized average yearly yields *per tree acre* were: dessert apples, 307 bu.; culinary apples, 392 bu.; pears, 239 bu. James Grieve was the most prolific dessert variety, with Worcester Pearmain a close rival: yields of both Lord Derby and Newton Wonder were close to that of Bramley's Seedling. Dr. Jules Guyot was the highest-yielding pear, with a margin of 80 bushels an acre over the more widespread variety, Conference. In spite of freedom from frosts, the fluctuation in yield from year to year was high, and averaged 144 bushels a tree acre.

There was little consistency in yield *movements;* very few varieties' yields moved in concert, and in the case of Cox's Orange Pippin, no two of seven farms in the same locality experienced identical yearly movements (i.e. higher or lower) in yield over the ten years. This is taken as evidence that comprehensive influences, such as temperature or cold winds, have less effect on yields than is commonly suspected; and that some factor on the farm, such as the management of the trees, makes a significant contribution to the yields obtained.

In the process of trying to trace the influence of management, the relationship between tree numbers and average yield per acre was examined, and also the relationship betwen "quality" (as determined by grading) and average yield per acre. No correlation between tree spacing and yield of Bramley's Seedling could be traced, but with Worcester apple and Conference pear higher yields were obtained at higher tree populations than at lower. High *quality* of crop was found to be associated with relatively high yield, and the maximum production of "Fancy" bushels an acre came, for one group of growers, at a "pack-out" of 55-60 per cent. Fancy grade or better, with a level of yield of about 240 bu. (of Cox's) an acre.

Average yields per acre (from mature trees) did not increase over the period. This phenomenon was widespread and can only be accounted for in part. A probable but unproven cause is the natural tendency of the trees to give a declining yield of marketable fruit after the age of 30-35 years. If this movement were to occur

at the same time as increasing selectivity in the markets (e.g. greater discounts on marked or small apples), growers could not expect their revenue per acre to increase as an orchard approaches middle life.

In view of its economic importance, more research might be directed towards methods of stabilising yields. The results now obtained suggest that a systematic field study of yield-generation in all its processes would be well worthwhile. For their part, growers could well give more attention to setting a full crop than to growing-on half a crop.

Some differences in yield *levels* can be ascribed to tree form and planting distance, which are less standardized than manuring or pruning practices, but on the whole, yield *movements* defy rational interpretation, which suggests that there is still a lot to be discovered about their origin.

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ACKNOWLEDGMENT

To record the yields of different varieties of fruit on mixed farms or mixed plantations under the stress of active harvesting is no easy task, and many farmers will only do it if they consider it worth while.

The Department returns grateful thanks to the farmers who have submitted yield records, and hopes that this publication will reward them in some degree for the trouble they have taken on the Department's behalf: it also hopes that the indications of the value of recording yields will persuade them to continue.

Ten Years' Yields

THE BACKGROUND: AN INDUSTRY IN TRANSITION

The swing to dessert fruit

During the ten years covered by this enquiry into yields of apples and pears in Kent considerable changes have taken place in commercial orchards. For once, the disturbing element is not the weather, but man; and the disturbance is not accidental, but purposive and made in response to the changed conditions in the markets. Trees of unwanted varieties have been "worked over" to varieties more in demand, overcrowded trees have been thinned out, uneconomic blocks of trees grubbed, and new plantations set out on a very large scale. The upshot of all this activity is the emergence of dessert apples to first importance where previously culinary apples had held sway.

The Ministry of Agriculture's periodical Fruit Censuses have made clear the net effect of these changes. For the county of Kent, numbers of apples and pear trees and the related acreage in 1944, 1951 and 1957 were as given below. The trends are clear:

(i) a big increase in tree numbers and acreage of dessert apples and of pears: 54 per cent more pear trees and 48 per cent more dessert apple trees in 1957 than in 1944.

(ii) a rise to, and subsequent fall from a peak in the acreage of culinary varieties of apple. The highest acreage was recorded in the 1951 census.

(iii) a much bigger reduction in the number of *trees* of culinary varieties: 24 per cent fewer trees in 1957 than in 1944.

Change in tree numbers and acreage, apples and pears in Kent, 1944-57

		1944	1951	1957
Dessert apples :	acres	12,890	20,619	23,560
	trees (1,000s)	1,886	2,520	2,782
Culinary apples :	acres	22,157	23,671	23,122
	trees (1,000s)	2,080	1,638	1,371
Pears :	acres	4,893	7,651	9,401
	trees (1,000s)	1,067	1,314	1,640

Source : Fruit Tree Censuses, M.A.F.F.

The overall figures for the county obscure two contemporary trends :–

(*a*) the outward spread of apple and pear growing from the older-established districts, and

(*b*) the growing importance of the eastern half of the county.

Spread to new districts

In 1939 there were a number of well-established fruit-growing areas in Kent, such as those around Sittingbourne and Marden, and within each area certain parishes were traditionally heavily planted with fruit. Commercial fruit production was then largely undertaken in parishes where at least 20 per cent of the agricultural land was under orchards, e.g., East Farleigh, Yalding*. Changes in the pattern of fruit growing could be followed from events in these parishes. This last statement is no longer as true as it was, because the proportion of the top fruit acreage in those same parishes fell from 64 per cent in 1944, to 60 per cent in 1957, and as regards *apples,* the proportion fell from 75 per cent in 1944 to 60 per cent in 1951. Implicit in this change, of course, is the switch to dessert apples and pears, which succeed best on lighter soils and a lower rainfall than is usual for culinary apples.

*Incidentally, the only parishes to achieve a status of considerably more than 67 per cent of land in orchards lie between Rainham and Canterbury.

Relative growth in the East

All fruit-growing areas, then, have not expanded equally. The type of change taking place is known and a study of orchard acreage changes in the different areas will show the extent of the movement.

Cherries apart, the geographical centre of fruit growing before 1939 was the culinary orchards in mid-Kent, south of Maidstone. Now, with the dessert apple and pear trade having become pre-eminent, East Kent* and North Kent, together, are equal in importance to mid-Kent and already provide half the supplies of all

*For this purpose, East Kent is an area east of the Stour valley from Ashford to Canterbury, and of a line from Canterbury to Whitstable.

dessert apples and almost certainly more than half of the county's Cox's and Conference.

By 1957, the newer area of East Kent was potentially equal in production capacity of dessert apples and pears to the more dispersed North Kent area, and though it did not have so many acres of dessert apples as the more important mid-Kent area, it had a larger production of more of the up-to-date varieties. The relative "size" of the three areas is shown in Figure 1 (frontispiece).

The acreage of apple trees of *all* ages in the three areas in 1951 (used to indicate the crop potential in 1957) is given below :

Relative importance of three fruit-growing areas in Kent: Acreage of apple trees of all ages, 1951

	East Kent	North Kent	Mid-Kent
	statute acres		
Dessert apples ...	3,209	2,919	6,018
Culinary apples	1,763	2,896	10,518

Thus it seems that each of the three areas has a different make-up of varieties at present and that it will take until 1965 or thereabouts for the industry to achieve its full re-constitution. The new plantings will keep output well up to the level of demand, and the only danger is that some of the half of all the dessert apple trees in the county now in mid-Kent may be kept in production too long. A fairly sharp campaign of grubbing the least productive trees on farms where there has been extensive new planting, would seem to be the best objective recommendation possible in this regard.

THE YIELD CENSUS FARMS: THEIR NUMBER AND LOCATION

Average number of farms

The year 1951 was also the mid-point of the ten-year span covered by the present survey. In such rapidly changing conditions as those outlined above, there is a possibility that a sample of fruit farms may cease to be representative of conditions as a whole, even though it might have been representative at the outset in 1947.

Initially, the Yield Census enquiry was meant to show up levels of actual yields and the differences in yields between varieties. Now the enquiry is established, the same yield figures are wanted for many more purposes. One such purpose is to provide collateral evidence with the Ministry of Agriculture's production estimates for Kent. These estimates are calculated from yield figures supplied by Crop Intelligence Committees, whose members rely largely on observation.

The yield results obtained would be much more useful for many purposes if they were representative of the county as a whole. One could then argue that what had happened on the yield census

farms would have been fairly general experience throughout the county. To further this end, the suitability of the sample as at 1951 was examined. The outcome was favourable on the whole, without allowing the enquiry to emerge unscathed. The sample of farms is mainly large enough, covering almost 10 per cent of mature (17 years or over) dessert apple trees, 7 per cent of culinary apple trees, and about 3 per cent of mature pears, in the fruit-growing parishes: but the three areas are not equally represented.

The location of farms

The recording farms are correctly spread over the three areas in *numbers*: but in terms of *acreage,* East Kent is over-represented and mid-Kent under-represented. The acreage, number of trees and average distance apart of the trees in Kentish parishes can be ascertained from the published (or available) statistics: and how the county figures and the figures for the recording farms compare is shown in the following table :–

The Yield Census farms and Kent as a whole

A. Proportion of county acreage contained in Yield Census farms.

	County	E. Kent	N. Kent	mid-Kent
		per cent		
Dessert apples	9.3	15	8	5
Culinary apples	6.8	12	8	6
Pears ...	3.3	—	Not known	—

B. Comparative regional distribution: acreage of trees over 7 years old in 1951.

	E. Kent		N. Kent		mid-Kent	
	dess.	cul.	dess.	cul.	dess.	cul.
			per cent			
In Yield Census	49	20	21	22	30	58
In Kent county	28	11	22	19	50	70

C. Comparative regional tree densities (av. no. of trees per acre).

	E. Kent		N. Kent		mid-Kent	
	dess.	cul.	dess.	cul.	dess.	cul.
In Yield Census	115	57	157	82	87	55
In Kent county	113	70	113	70	108	76

The effect of over-representation of East Kent in the sample is to make the results more appropriate to the county as a whole in 1957 than in 1951. By 1957, for example, the coverage in the sample of dessert apple trees had risen to 10.9 per cent of those in the county, of culinary apple trees to 9.4 per cent, and of pear trees to 5.5 per cent.

Not all the farms, of course, grow all types of fruit. Areas of less than one acre of the main varieties are recorded but yields for these areas are not used in the published results. The minimum number of separate records embodied in an average yield is five (Early Victoria) and the maximum number 44 (Bramley's Seedling). For the present, the sample evidently lacks records from a number of the larger and older fruit farms in mid-Kent. Originally this type of farm had been avoided, because its orchards are often very mixed (making recording difficult), or else the farm enterprises are mixed (making the farmer relatively careless about fruit yields) ; but this present failing can be remedied for the next ten-year period. All in all, however, there is little lost by having only yield records from farms where fruit growing matters.

THE MEANING OF "YIELD"

Basic notions: the grower and yield

The subject of commercial yields of apples and pears is now considered in progressive detail and principle, on the assumption that results have been obtained which accord with practice on the majority of seriously-managed, somewhat specialized fruit farms or enterprises in the county, with the proviso that the findings are more appropriate to the eastern part of the county than to the western part.

Sixty seven farms have regularly sent in their annual yields, and the area recorded for the 1957 harvest was 3,022 acres. This was 93 per cent more than the area in 1948. The recorded area must naturally tend to increase, because each year young plantations qualify by age for inclusion in the Enquiry. Peak *quantities* recorded (in the later years) were approximately 500,000 bushels of dessert apples, 500,000 bushels of culinary apples, and 100,000 bushels of pears.

Yields of trees *below* 17 years old, though separately recorded, are not included in the published annual averages for the main commercial varieties. It was originally thought that a fruiting tree could not be considered to have "settled down" until it was 17 years old.

Precision in recording yields is much to be desired, but far more difficult to realise. Many packhouses have found how hard it is to keep year-to-year check upon their members' tree numbers when their orchards are in such a fluid state as at present. Farms co-operating in the Yield Enquiry are visited less than once a year,

on average, by the Department's staff. It may be thought that this lightness of coverage leaves room for a wide margin of error: but it is believed that the cumulative error is not significant in relation to the results required—yields as different, for example, as Cox's and Worcester Pearmain's, or Bramley's and Grenadier's. In support of this belief three factors may be quoted:

(i) the keenness of growers in checking their own results;
(ii) the exclusion of mixed orchards;
(iii) the capacity for correcting results back to their time of origin once a mistake is uncovered.

The actual "yield" as given in this report is an average and a compromise figure, being neither the volume of fruit borne on the trees nor the volume of fruit consigned to market. Some contributing growers record yields as picked, some record sales but do not store, and some record sales after cold or gas storage. By taking the average figure derived from the various marketing policies practised, it is believed that a single figure of general utility is obtained. The quoted yield is not too different from the "natural" yield to proscribe yield *movements* being tentatively related to physiological features in the tree: "natural" yield would only differ from quoted yield if there were a big proportion of "smalls" or "culls" borne on the tree, and this feature is far removed from good commercial practice. On the other hand, the quoted yield is not too different from a "marketed yield" for the commercial propensities of each variety to be adequately described by the quoted yield.

Large and small farms

The quoted yield is most likely to be misleading when applied to the smallest and largest farms. Other things being equal, small farms have higher yields than large farms because, on small farms (*a*) each tree is given greater attention; (*b*) site and situation are often more favourable, e.g. no frost pockets, "hot spots" or the like; and (*c*) allied to higher initial yields is a more complete utilization of the crop—early drops picked up, inferior quality fruit sold locally, no storage losses, and so on.

Large farms, on the other hand, tend to be associated with high standards of grading and packing, with long-term storage, and with a different attitude to culls than on the small farm. In the years in question, however, wastage of fruit after picking was not a factor to be reckoned with, and only on the largest culinary apple farms are year-to-year differences in degree of utilization of the crop likely to invalidate the use of stored-cum-process disposals as the measure of the commercial yield of fruit borne on the tree. To offset this weakness in the data, a change in annual average yield between one year and another has not been considered significant* if of the order of less than 10 per cent. No tendency can

* *Statistical* significance is dealt with elsewhere.

be observed for certain varieties to be more frequently grown on small farms than large, though the large areas of Cox's included may make the average yield for this variety unrepresentative of yields for good small farms.

Readers are therefore asked to remember two things about these yield figures. First, that "yield" means yield of fruit having value: fruit left on the ground is not included in "yield", but fruit picked and sold for processing, and fruit picked up and bagged for processing is included. Quoted yields will exceed the volume of fruit passing to the trade when much fruit that has been picked cannot be sold. Only in exceptional years like 1958 does this happen with the most important varieties. Secondly, readers are reminded that yields are expressed *per tree acre*. A common area basis of "number of trees x distance apart" has been adopted for all the orchards in the Enquiry. No allowance has been made for gaps in the main plant: a very "gappy" orchard would tend, consequently, to have a relatively low yield. The same effect would occur where large trees significantly fail to cover all the ground in the orchard not required or desirable for access to the tree, but in the writer's opinion, only one plantation on one farm is affected in this way.

There is consistency in the records, moreover, in one important respect. The growers have not changed their marketing policy during the period of the records. There is no switching between "picked bushels" one year and "marketed bushels" the next on the same farm.

Bushel weights have been standardized at 40 lbs. for apples and 48 lbs. for pears.

TEN YEARS' YIELDS

(*a*) Average, and for each variety

After this preamble, actual yield figures can be safely, but not entirely satisfactorily, quoted. The results are too numerous to be quoted individually, and average results obscure much variation which might be significant if more were known about the subject.

An average yield for each of the ten years has not been calculated, but separate varieties' yearly yields are given in tables at the back of the report, and the movements of average yield per acre for the leading varieties are shown in Figures 2 and 3 (pp. 49 and 50). The ten-year average yield for each variety is given below.

Mid-way through the period, 920 acres of mature dessert apples, 1,000 acres of mature culinary apples, and 300 acres of pears were being recorded, and the summarised results for the ten years are:

Average yields by category of fruit, 1948-1957

	per tree acre *bushels*	per tree *bushels*
Dessert apples (40% Cox's, 33% Worcester)	307	2.56
Culinary apples (80% Bramley's) ...	392	6.88
Pears (67% Conference)	229	1.25

General experience may therefore be summarized as :
$2\frac{1}{2}$ bushels a tree for dessert apples,
7 bushels a tree for culinary apples,
$1\frac{1}{4}$ bushels a tree for pears.

In greater detail, yields of the most widely-grown varieties, arranged in descending order, were :

Average annual yields per tree acre, 1948-1957

	No.of records (1952)	Acreage (1952)	Yield per tree acre (1948-57) *bushels*	Standard Deviation *bushels*	Year of highest average yield
Dessert apples					
James Grieve ...	9	9	402	83	1951 1955
Worcester Pearmain ...	32	309	372	85	1950 1951
Ellison's Orange ...	9	9	317	59	1953
Miller's Seedling ...	15	71	314	86	1949
Charles Ross ...	9	5	293	100	1955
Beauty of Bath ...	19	30	278	68	1951
Laxton's Superb ...	15	77	275	113	1955
Cox's Orange Pippin ...	26	416	256	49	1951
Culinary apples					
Bramley's Seedling ...	44	765	423	75	1950 1951
Lord Derby ...	23	129	392	85	1950 1952
Newton Wonder ...	26	78	385	100	1952
Grenadier	19	69	319	49	1950
Early Victoria ...	5	10	275	56	1949
Lane's Prince Albert ...	8	8	217	70	1955
Pears					
Dr. Jules Guyot ...	9	10	312	100	1952
Doyenne du Comice ...	7	21	271	117	1949
Conference	14	107	232	71	1949
Laxton's Superb ...	8	29	207	46	1949
Williams' Bon Chrétien	7	7	193	86	1956
Fertility	6	9	191	46	1954

(*b*) Alternation of high and low yields on single farms

The word "biennality" has not been used in the present context because the incidence of the "up and down" behaviour of yields of most varieties of apple in commercial practice as revealed in the yield records is thought to be different from that of biennial bearing associated with greater or less production of blossom each year.

For the first time it is now possible to measure the variation in annual yield of the most popular varieties as experienced by growers. The results are presented in terms of a "coefficient of annual variation", formulated for each variety as:

$$\frac{\text{the average change in yield per acre (on all farms) from one year to the next} \times 100}{\text{the average yearly yield per acre for the 10-year period}}$$

All farms' results have been included in this analysis, so that the effects of location, of management and of age—which affect varieties differently—have contributed to the observed result in addition to the known features of regularity or irregularity of bearing of the variety concerned as determined under experimental conditions.

From an analysis of 2,500 cases it emerges that Worcester Pearmain and James Grieve were jointly the most regular croppers amongst dessert varieties, Lord Derby among culinary varieties. Laxton's Superb and Lane's Prince Albert were respectively the most irregular croppers.

The full table is:

Dessert varieties	Coeff. of variation	*Culinary varieties*	Coeff. of variation
Worcester Pearmain ...	42	Lord Derby	44
James Grieve	42	Early Victoria	47
Cox's Orange Pippin ...	55	Bramley's Seedling ...	53
Beauty of Bath	55	Grenadier	65
Charles Ross	61	Newton Wonder	80
Miller's Seedling	66	Lane's Prince Albert ...	84
Ellison's Orange	67		
Laxton's Superb	84		

What can be gathered from this array of summarised figures?

As regards yield . . .

(i) that the dessert varieties now becoming out-moded, whether used as pollinators (James Grieve) or as early varieties (Miller's Seedling) gave above-average yields. Will their replacements be as good?

(ii) that the average yield per acre of Worcester Pearmain is 50 per cent above that of Cox's Orange ;

(iii) that compared with yields of dessert varieties, *average* yields of culinary varieties are low on many farms (sales to the fresh market would amount to an average of about 360 bushels a tree acre, or only 325 bushels a statute acre);

(iv) that, happily, on the whole the consumer prefers the higher-yielding varieties of pear.

As regards management . . .

(i) that the grower in Kent has no high-yielding winter-season dessert apple which he can aim to grow and market competitively early in the year. The performance of *Jonathan, Granny Smith* and *Late Cox* will be watched in this connection ;

(ii) that the "good" year for apples is not the "good" year for pears and *vice versa ;* pears have cropped well when apple crops have been light (see the right hand column of the table on p.13) ;

(iii) that certain seasons favour certain varieties ; this point is taken up again later ;

(iv) that *Bramley's* has no rival for its purpose ;

(v) *that the average change in yield in an apple orchard from one year to the next, even in this period of absence of serious frost damage to crops, was* 144 *bushels a tree acre —equivalent to* 40 *per cent of a "normal" crop.* Is not this "swing" much too high for comfort?

Distribution of yield per acre. Not all growers, of course, were equally successful in growing each variety. The distribution of yield per acre of the five most important varieties of apple and pear on the farms in question is shown in Figure 4 (pa. 51). The central column in each small diagram refers to farms' yields which are within (plus or minus) 10 per cent of the *average* yield of the variety concerned, and the outside columns refer to yields that are at least one quarter higher or lower than the average ; the intermediate columns cover the range 10-25 per cent of average yield. Two features are at once noticeable :

(i) that relatively few growers are *average ;* their yield results are either good or bad (see diagrams for *Lord Derby* and *Conference*).

(ii) that for all varieties, 20-35 per cent of growers get only low yields.

(*c*) For each area

Average yields for the three most important varieties, as recorded for each of the three natural fruit growing areas in Kent, are given below. The figures are not known to be biased in any way, but cannot be held to be statistically significant. The different *potential* of each area (if the potential *is* different), must be somewhat obscured by the trees in the different areas having different average ages: for example, mid-Kent has more old *Worcester* trees than East Kent.

Average annual yield, 1948-57

	East Kent	North Kent	mid-Kent
	Bushels per tree acre		
Cox's Orange Pippin ...	341 (115)	233 (157)	221 (87)
Worcester Pearmain ...	446 (115)	384 (157)	286 (87)
Bramley's Seedling ...	381 (57)	366 (82)	507 (55)

(*Note.* The figures in brackets are the average number of trees per acre of dessert and culinary varieties, from page 10).

There is as yet no evidence that a grower can get an income-levelling effect by choosing his *varieties* carefully. Figures 2 and 3 (p. 49-50) will tell the reader that each variety has idiosyncracies of yield and this opens up a prospect that of two varieties equivalent in yield and market price, one might be preferred because its yield movement (apart from the quinquennial year when all varieties are either "on" or "off") may run counter to that of a grower's other varieties. There are not enough records to show whether any of the newer varieties—Laxton's Fortune or Lord Lambourne, for example—can fulfil this requirement.

YEAR TO YEAR FLUCTUATIONS IN YIELD

The behaviour of different varieties

The six diagrams comprising Figs. 2 and 3 show the movement in annual yields of pairs of varieties which are usually either complementary or alternatives to each other.

Although some of the varieties featuring in this analysis are not important enough to deserve closer study, they can be used to help to demonstrate the separate types of movements in yield. Presumably the newer varieties will have characteristics of their own, too.

Briefly, as can be seen in the diagrams, there is a disposition to biennality in most varieties' bearing—some two thirds of the movements in yield from one year to the next shown are contrary and about one third are in a similar direction (i.e. up two years in succession or down two years in succession). As these are average results for many farms, and no one has claimed biennial incidence

for weather effects, it looks as if causes other than weather must be held accountable for the change in level of yield from one year to the next.

Nevertheless, each variety behaved individually. No two varieties' average yields moved in the same *direction* every year for ten years, let alone to the same degree in the same direction. This statement also holds good for movements exceeding 10 per cent change from the yield figure for the previous year, which, as was said earlier in the report, could be considered not to be due to changes in the volume of fruit picked but not sold (as might happen with "picking over" the early varieties) or to mis-recording. In other words, growers' experiences with the same variety in the same year were dissimilar.

Dessert varieties

Closest similarity in movement in annual average yield per acre was to be found between two early varieties, *Miller's Seedling* and *Beauty of Bath*. What have these two varieties in common? According to the text book, these varieties are the first to flower, and flower at the same time, for the same period. However, before too much is taken for granted, let it be said that the recorded trees were not mainly on the same farms, nor all in the same parts of Kent. Relatively few farms are concerned here and it can be seen from the records that the differences between yields on single farms are mainly in levels of yield and in the size of fluctuations, not in the *direction* in which yields move. *Miller's* apparently missed its "off" year in 1952 on these farms.

Since trees of these two varieties are in plantations under different management, it must be presumed that some common factor causes the similarity in changes in yield from one year to the next. Most growers would say the weather was causative; but if so, local variations in climate (which are adduced elsewhere as causing differences in single farms' yields) cannot have had much effect at any time in the ten years—it is inconceivable that there have *not* been local variations in temperature and wind strength and direction at blossoming time over an area as large as Kent during the last ten years; or that local variations in climate have their effect late in the season but not early in the season.

Here, then, is a case where neither management nor climatic conditions alone had a decisive effect upon the course of yields —unless management practices were identical.

Annual average yields of *Charles Ross* and *James Grieve* also had much in common. Again, these varieties may be presumed to have been subject to the same general weather conditions at blossom time. In this case, too, the two varieties were largely grown on different farms in different parts of Kent. If weather influences are assumed to be general in their effect (and this would mean that after-effects of weather influences were common to both varieties) then

either management practices on the farms concerned were similar, or if different, had no observable effect upon the course of yields. Yet both these varieties failed, relatively, in 1953—*Ross* on all farms, *Grieve* on some farms. No other varieties were similarly affected in any part of Kent, and *Worcester,* on the same farms as *Ross* and *Grieve* and *Ellison's* bore particularly well, although normally flowering at the same time. This latter phenomenon appears to rule out the weather as the prime cause of yield failure in 1953, and this argument is supported by the fact that some *Grieve* plantations were unaffected in 1953.

A rational explanation of these yield movements is difficult to find. Large-scale weather effects are observable (as in 1949 and 1956) but when these are not decisive, micro-effects become important, affecting single orchards, or parts of orchards, separately. These seem to have a chance occurrence and may or may not be counteracted by good management.

Movements in yields of *Cox* and *Worcester* have little in common, although they ostensibly flower at the same time, and are grown on the same farms. In four seasons of the ten, average yields moved in the same direction, in four seasons in opposite directions. *Cox,* as the most carefully-managed variety, shows less actual fluctuation than *Worcester,* but, unlike all other varieties, had its best crop in 1951. Here are two widespread varieties, subjected to similar weather influencees, which do not behave similarly, and the supposition is that management is affecting the yield of *Cox.*

Culinary varieties

Among culinary varieties of apple, *Grenadier* showed an unmistakably biennial habit, and was not disturbed in its yield cycle whilst *Early Victoria* often ran counter to it. These two varieties are on different farms, and these are not the same farms as was shown, in the case of *Miller's* and Beauty of Bath, not to make any difference to the *way* yields moved. The presumption here is that either these varieties were subject to *different* weather influences, or that their yield each year was partly determined by physiological factors, induced by the way the trees were managed.

Both *Bramley's Seedling* and *Lord Derby* have had a five-year period of low yields, but apart from that, these two varieties were affected in different ways each year. In this case, weather influences could have been decisive, because yield movements of Bramley's on farms also growing *Derby* are not similar to those of Bramley's generally (the latter being more dispersed).

Pears

The few pear yields available tend to confirm the weather-determinant principle. The same farms grew three varieties—Conference, Williams' and Laxton's Superb. Conference and Williams',

both flowering in mid-season, show the same course of annual yield (not shown in Figure 3) with William's having much wider fluctuations.

In the other hand yields of Laxton's Superb, flowering later than Conference—but again on the same farms as Conference—were clearly out of phase with yields of Conference.

Practical implications

Again the practical value of these figures (tardy though they be) is to suggest to the grower :

(i) that if he grows two varieties of such similar behaviour as James Grieve and Charles Ross for their own sake and not as pollinators, he could, if their market values were equal, concentrate on the variety that serves him better than the other ;

(ii) that of the early apples, Miller's Seedling and Beauty of Bath behave similarly : on this score the grower who has only one of these two varieties is quite right in not regretting that he has them both ;

(iii) that if Cox's is his mainstay, he cannot find a good "hedge" in any of the better-known varieties of apple. Cox's itself under good management, is proving to be one of the most regular croppers. Worcester Pearmain has "on" years, but to judge from experience in Kent, these coincide with an average, rather than a low crop, for Cox's ;

(iv) that, similarly, if he grows Bramley's Seedling, he has to abide by the performance of this one variety, Lord Derby is no good alternative ; it can of course usefully *complement* Bramley ;

(v) that if he feels he must have an early culinary apple, he could safely decide between Grenadier and Early Victoria on the basis of net returns an acre—he is not likely to feel the absence of the other if he plants only the one variety ;

(vi) that if he relies on Conference among pears, he will have to depend on it very largely : no mid-season variety's yield moves counter to that of Conference, but Laxton's Superb has cropped well when the Conference crop has been light.

THE PATTERN OF CHANGES IN YIELD FROM YEAR TO YEAR

How explain the "off" year ?

So far, it has been established that the behaviour of the yield of single varieties is very individualistic, and that neither time of

flowering nor common management has an observable effect upon the course of yields of one variety in relation to another, in the absence of decisive weather effects.

To stabilize yields, of course is not the same problem as that of procuring a high level of yield ; it is rather a question of understanding what makes a minority of growers have higher-than-average yields in the years when the majority have below-average yields for the same variety. Is the unexplained "off year" in any orchard inevitable? How serious is the biennial-bearing inclination in many varieties? How does it come about that almost adjacent farms can maintain different alternations of "on" and "off" years for the same variety?

Earlier, it has been shown that with some dessert varieties (which are relatively immune to slight frosts) in the absence of frost damage, yield movements are similar for two varieties flowering early in the season, although on different farms, whereas later in the season yield movements are different for two varieties on the same farms. There is less consonance generally between culinary varieties and between pears, but this may be due to susceptibility and greater exposure to weather influences. The most probable theory to account for the yield movements of dessert varieties of apple is that, in moving from the time of early flowering to the time of late flowering, physiological changes are taking place in the tree which change its susceptibility to external influences.

A more refined analysis of yield movements has been attempted in an effort to throw light on these questions, but no clear-cut results emerge at the end of it. Briefly, a four-fold division of the farms was made, so that average yield movements were traced for :

(*a*) two pairs of varieties flowering at the same time on the same farms (Ellison's and Grieve ; Cox's and Worcester) ;

(*b*) the same two pairs of varieties flowering at the same time on different farms ;

(*c*) two pairs of varieties flowering at different times on the same farms (Derby and Bramley's ; Grenadier and Early Victoria) ;

(*d*) the same two pairs of varieties flowering at different times on different farms.

The test applied in this analysis was whether the recorded yield for each variety each year was above or below the ten-year mean value for the variety in question on the farm concerned. The results are as follows :

On the same farms

(a) *Varieties flowering at the same time.*

	Cox's and Worcester *per cent*	Ellison's and Grieve *per cent*
Proportion of occasions when yields of the two varieties moved in concert	55	54
Distribution of similarity of movement by farm :		
more than $\frac{2}{3}$rds ...	26	20
$\frac{1}{3}$rd–$\frac{2}{3}$rds ...	61	80
less than $\frac{1}{3}$rd ...	13	nil

(b) *Varieties flowering at different times.*

	Derby and Bramley's *per cent*	Grenadier and Early Victoria *per cent*
Proportion of occasions when yields of the two varieties moved in concert	61	50
Distribution of similarity of movement by farm :		
more than $\frac{2}{3}$rds ...	37	43
$\frac{1}{3}$rd–$\frac{2}{3}$rds ...	45	43
less than $\frac{1}{3}$rd ...	18	14

Because larger numbers of records are concerned, the results for Cox/Worcester and Derby/Bramley are to be preferred to those for the other varieties.

How significant these figures are is a matter for conjecture, and it has to be borne in mind that the two main culinary varieties were probably subject to more potent weather influences than the two main dessert varieties : but even so, *on the same farms* yields of the two varieties compared have only moved in concert about six years in ten, and the fact of different flowering time does not seem to have affected the issue greatly (55% and 61% respectively).

Moreover, each pair of varieties shows the same behaviour on a distribution analysis : in all cases dissimilarity is uncommon, two-thirds similarity is relatively frequent, but a fifty-fifty relationship (i.e. one year in concert, one year contrary) seems the general experience, whether the varieties are flowering at the same or different times. Observe that between one-third and two-thirds similarity is the most common experience.

On different farms

(a) *Varieties flowering at the same time.*

	Cox's and Worcester *per cent*	Ellison's and Grieve *per cent*
Proportion of occasions when yields of the two varieties moved in concert	50 (55)	57 (54)
Distribution of similarity of movement by farm :		
more than $\frac{2}{3}$rds ...	14 (26)	20 (20)
$\frac{1}{3}$rd–$\frac{2}{3}$rds ...	72 (61)	60 (80)
less than $\frac{1}{3}$rd ...	14 (13)	20 (nil)

(b) *Varieties flowering at different times.*

	Derby and Bramley's *per cent*	Grenadier and Early Victoria *per cent*
Proportion of occasions when yields of the two varieties moved in concert	55 (61)	52 (50)
Distribution of similarity of movement by farm :		
more than $\frac{2}{3}$rds ...	17 (37)	20 (43)
$\frac{1}{3}$rd–$\frac{2}{3}$rds ...	63 (45)	80 (43)
less than $\frac{1}{3}$rd ...	nil (18)	nil (14)

Note. Figures in brackets are those previously quoted for results on the same farm.

Comparative behaviour

It is not suggested that these figures *prove* anything. But bearing in mind that they relate to the extent to which yields of apples rise or fall in concert (the inference being that they have been subject to the same influences) the similarity in the results is remarkable. Apparently, whether two varieties are on the same farm or on different farms, and flower at the same time or at different times, their comparative behaviour will be the same and in five years out of ten yields of *both* varieties will move up or down in concert, and in the remaining five years the movement in yield will be contrary.

Two *tendencies,* however, emerge from this analysis. First, that yield movements of all varieties of apple have greater similarity on the same farm than between different farms. Apparently, management (or location) does count for something, because there is also greater similarity between varieties flowering at different times on the same farms. Secondly, that yield movements of

culinary varieties are more subject to comprehensive influences than are dessert varieties.

Another word of explanation may be desirable. Taking the farms singly, not all varieties' yields are low and high in the same year, and, in a predominantly good year for one variety, yields are not high on all farms growing that variety. In other words, even on commercial farms, the year of high production of, say Cox's Orange, is the year when two-thirds of the growers have an above-average crop, and one-third a below-average crop ; the year of low production is when two-thirds of the growers have a below-average crop and one-third an above-average crop. The ratio between " on " farms and " off " farms has not been much lower than 2 :1 for any dessert variety in any one of the ten years' records. With culinary varieties the ratio widens to about 3 :1 in the absence of frost years, but even in 1955, 10 per cent of recorded growers of Bramley's, and in 1956 25 per cent of growers of Lord Derby, experienced *above-average* crops.

To sum up, it is finally apparent that the prevailing weather is only one of the influences and has not been the deciding influence in deciding the level of yield on individual farms in the year of its occurrence. *Residual* effects of weather influences over the following seasons cannot be traced through the yield records.

There are not enough local weather records, or records of the blossoming peculiarities of each season, to enable these yield movements to be related to observed natural phenomena. Why almost each variety should have a separate pattern of yield movements must remain a mystery. It looks first of all as if the weather at pollinating time is a deciding factor, and that one or two fine (or finer) days experienced by one variety and not by another, can make all the difference to the " set " of fruit and subsequent yields. If this is so, the " ideal " condition may well be widespread but short-lived in most seasons whereas they are usually thought of as being *localised.* All in all, it seems that theories of weather-determination of yields would have to rely on a proposition that in non-calamitous seasons, almost each orchard is affected separately, because its yield moves either up or down notwithstanding the comprehensive occurrence of natural phenomena like rain, temperature and wind.

One is forced back to the conclusion that it is the interplay of weather and management, and the combination of current and past occurrences, which determine the initial size of crop in any one year. It seems fairly clear that one season's weather has not been, in the last ten years, the all-pervading influence expected. Consequently growers have something to hope for from giving orchards individual protection and attention : in this way they could hope to temper all but the most calamitous intervention of Nature.

As a next step, the effect of location on the course and level of yields is examined. Weather influences are to some extent related to location. *Bramley's* yields in the Marden area are compared with those in the High Weald, and yields of *Cox* and Conference between East Kent farms and West Kent farms.

KNOWN CAUSES OF DIFFERENCES IN AVERAGE YIELDS

The effect of location

Bramley's Seedling. Location has more relevance to culinary varieties than to dessert varieties. To be above the 100ft. contour seems to have been worth about 30 bushels a tree acre a year to a mid-Kent grower of *Bramley's* in the relatively trouble-free period since 1948. Average yields per tree acre for a sample group of six large farms in the Staplehurst-Paddock Wood area, and for a sample group of six large farms on the higher land just to the south of this area, all farms being well-managed, were :

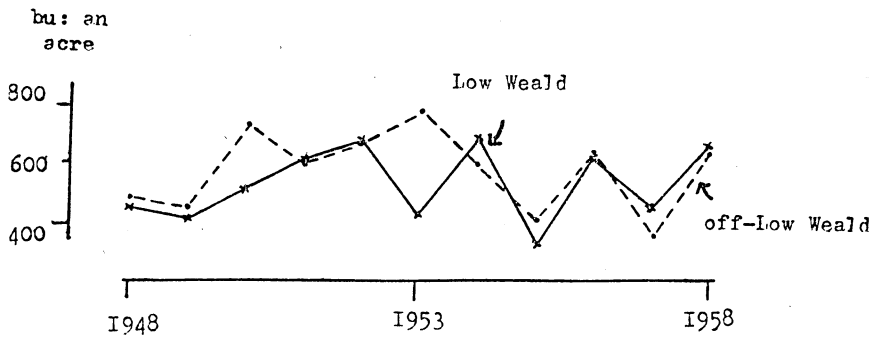
Low Weald group	520 bu. a tree acre
Off-Weald group	550 bu. „ „ „

The difference was entirely due to occasional crop failures on the farms in the plain. Yields moved in concert for eight out of the eleven years : 1953 was the best year for growers off the plain, 1954 the best year for those on the plain.

The rising trend in yield after 1948, remarked upon in an interim report,* is again evident, with a change in the trend setting in for 1953. Only the growers concerned will know whether a halt in their operations on the tree, or weather influences, or some unknown factor, brought about the change. It would seem (from the diagram below) that these two groups of farms have been subject, latterly, to the same influences, whether physiological or climatic. Incidentally, yields on these farms in 1958—the year of greatest national production since 1947—had been topped twice in the previous decade, in either 1953 or 1954.

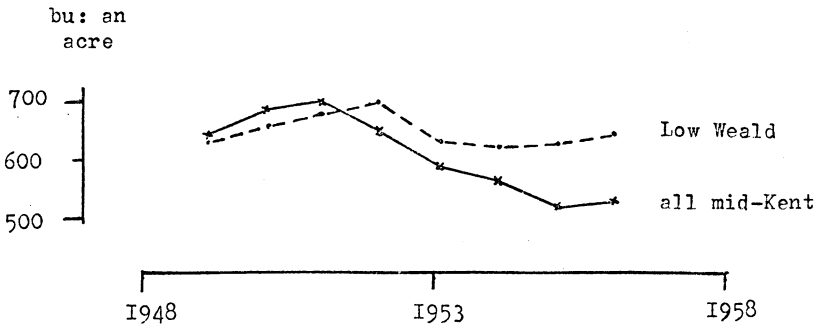
* *New Light on Apple Yields in Kent.* Folley and Rowe, Wye College.

Comparative yields of Bramley's Seedling, 1948-58



The *trends* in yield for these two samples of farms were similar, but different trends became apparent in the average yield for *all* recorded Low Weald *Bramley's* and for all recorded *Bramley's* in the mid-Kent area. Comparative four-year average yields are shown below. The specialized growers in the Low Weald have clearly succeeded in arresting the decline in yields to a greater extent than the more mixed growers elsewhere in spite of one more frost ; the mixed growers, probably, having become more interested in dessert sorts.

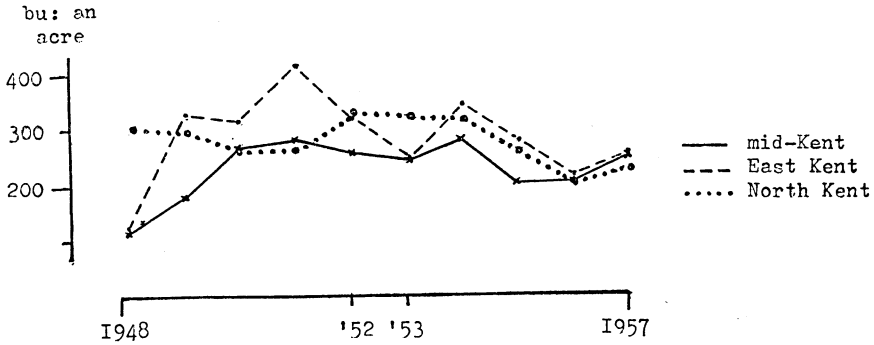
Comparative trends in yield, Bramley's Seedling, I948-58



Unless yield movements be considered cause-less and self-acting, the presumption in this case must be that trees away from the Low Weald have been subjcted to a different set of influences from those on the Low Weald. The *course* of annual yield movements of *Bramley's* moreover, has been the same in all areas of Kent : in the neighbourhood of Marden and Paddock Wood, however, the adverse effects were tempered—could it be . . . by better management? Weather-theorists are here confronted with two questions. First, why (in the absence of killing frost) do some orchards run counter to the general movement in yields? Secondly, why do the seasons *alternate* between satisfactory and unsatisfactory?

Cox's Orange and Worcester Pearmain. Of the dessert varieties, only *Cox* and *Worcester* can be followed in detail. The pattern of yield movements of Cox's has its own interest. Yields on the farms in East Kent and in mid-Kent have moved in concert throughout : 1948 was a particularly bad year in these areas. Farms in North Kent, however, were out of phase with those elsewhere during the first six years ; latterly, all three regions' yields have moved more in concert (see the diagram on page 27).

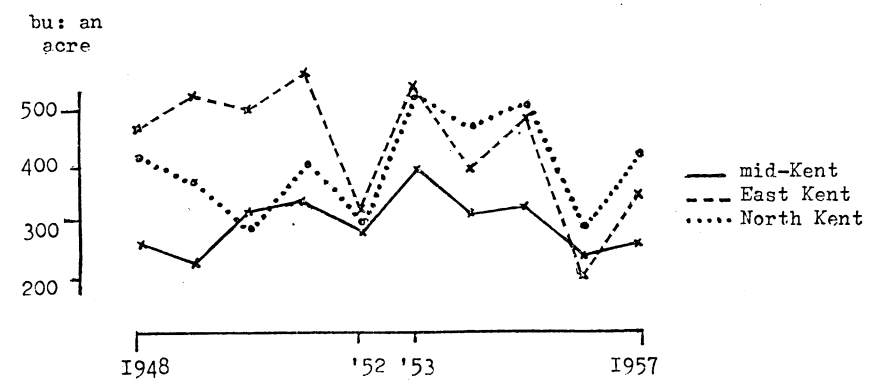
Comparative yields of Cox's Orange Pippin, I948-57



Again, the effect of some comprehensive influence is apparent between 1954 and 1957 : it could be either management *or* weather, because, as will be shown later, there was great uniformity in treatment of the *Cox* trees.

The same theme, with variations, is evident in the yields of *Worcester Pearmain* (see below). East Kent and mid-Kent are again in concert for nine years, with North Kent showing similar annual movements since 1950. The *Worcester* picture, perhaps, adds something new to the argument so far. Worcester and Cox are largely grown on the same holdings and often pollinate each other. Worcester has the reputation for regular bearing, but its annual fluctuations in yield are shown to be greater than those of *Cox,* and *Cox* did not share in *Worcester's* relative failure in 1952 and again in 1956. In the next section it is shown that failure in 1952 was largely on the bush type of tree, on Cox-growing farms. *Cox* is the most carefully-managed variety, and it seems that, over the last ten years, its resistance to weather effects has been significantly increased.

Comparative yields of Worcester Pearmain, I948-57



One final point may be worth noting. In the east of the county, the average annual yield of *Worcester* exceeds 400 bushels an acre. In mid-Kent, the average is lower, and this is thought to be due to the higher proportion of older half-standard trees at wide spacings. The point is taken up in the next section.

The effect of tree spacing

Cox's is so relatively new a variety to many growers that there are no great differences in tree spacings between one *Cox* plantation and another. With *Bramley's,* on the contrary, there has been time for considerable differences to emerge in age and distance apart of trees. With *Worcester,* too, there are both older half-standard trees on, say, Crab stocks and newer bush trees on M.II (mainly). Among pears, the tree's form gives opportunity for much closer planting than apples, but not all growers take advantage of it.

Bramley's Seedling. The size of a *Bramley* tree has no decisive bearing upon yield *per acre.* Orchards carrying 27-50 trees to the acre had an average of 470 bushels an acre, those carrying 51-76 trees to the acre an average of 471 bushels. No correlation could be established between tree spacing and average yield per acre. Other factors were obviously more important. Lopping-off topmost branches to secure economic-to-pick fruit of reasonable size may be partly responsible for this result. In sum, it appears that a grower can reasonably expect average performance from trees of all sizes, subject to the effects of age and location.

In 1954, only 4 per cent of farms recording yields of *Bramley's* failed to set an above-average crop. If it could safely be assumed that all trees of every size were equally favoured by the season, their performance was very even, for the average for each size-group in that year was as follows :

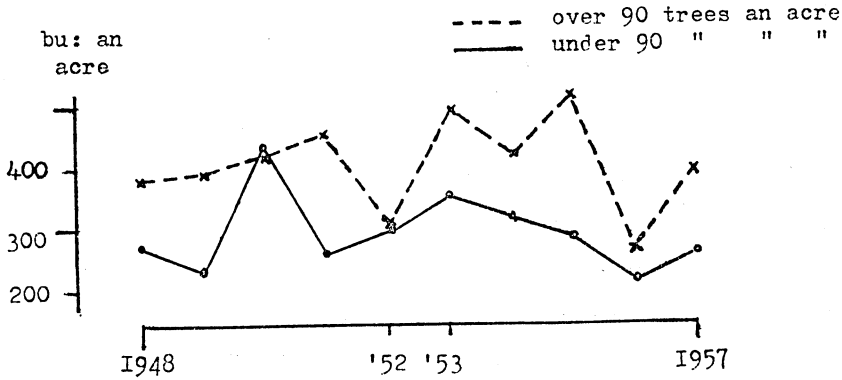
No. of trees per acre :	26-35	36-45	46-55	56-65	66-75
No. of farms ...	9	8	12	7	12
Bushels per tree acre	534	470	523	519	534

Worcester Pearmain. With Worcester Pearmain, differences in yield per acre emerge which are greater than any possible margin of error, but not all the difference is due to the one factor, spacing. The ten-year average yields were :

below 90 trees to the acre ... 294 bushels a tree acre
above 90 „ „ „ „ ... 403 „ „ „ „

Neither the relatively close planting of young trees nor the careful siting of post-war orchards have any effect on these figures, because all the trees concerned were at least 17 years old. Only in 1950, when a number of orchards of widely-spaced trees carried a very heavy crop, and again in 1952, when the bush crop failed, did the average yield of the under-90 group compare with that of the over-90 group. See the diagram on page 29.

Yield in relation to tree spacing, Worcester Pearmain



The differential in yield per acre may be due to the under-90 group being either older or on more vigorous rootstocks or in different areas from those in the above-90 group. In any case, the evidence is further support for the argument, developed elsewhere, for keeping as close a plant as is tenable in any given conditions. Costs on a 40-tree acre of orchard are not so much less than costs on a 120-tree acre as to make the wider spacing more economic than the closer.

Conference. The *Worcester* story is repeated with Conference pear—higher yields were obtained where tree numbers per acre were greater. Only 25 farms are concerned here, and the differences in average yield may be partly the effect of a small sample ; the age factor is probably important, too. Average ten-year yields of Conference were as follow :

11 farms with below 150 trees to the acre — 227 bushels an acre
14 farms with above 150 trees to the acre — 273 bushels an acre

It is noted in the section on quality of fruit as affected by yield, that extremely high yields per acre of pears, such as might have been obtained in 1958 from closely-planted trees, were accompanied by a falling-off in market quality.

HIGH YIELDS MEAN HIGH PROFIT

Why study yields ?

High average physical yields per acre have an important bearing on a grower's financial future. Whether the season be good or bad, a grower will tend to be better off with a high marketed yield than a low yield. Consistently high yield never broke a grower, like too low a yield.

A fruit tree's crop is at least as much a natural phenomenon as an economic phenomenon, but while attention to yields is a cardinal point of the economist's approach, studies of yield seem to have been neglected by natural scientists. For one thing, yield studies are not amenable to laboratory techniques: for another, an adequate observational study would involve thinking-out a new range of techniques for measuring and describing physical conditions in orchards: lastly, a large team of workers would be required for observation on an adequate scale, because the natural range in many physical phenomena is at present unknown. For these reasons, progress towards a better understanding of yield variations may be slow. And in any case useful results from observational studies would be by no means assured.

Growers themselves are often neglectful of yield as a feature of their farming. Bombarded by technical data, they are mentally conditioned towards growing a clean crop rather than a full one. Prizes can be won for cleanliness in the orchard. A high yield is its own reward and does not need a foster-industry. In the present state of knowledge, more growers can grow a clean crop than a full or regular crop (as can be statistically demonstrated). Whilst acknowledging that growers have progressed up to this point, it is surely not the final stage of their accomplishment.

Comment on the popular attitude to yields is felt to be justified because the economic future of fruit growing must depend in part upon a rising level of yields. Without a progressively higher response to a standard level of cultural attention—more fruit for *relatively* less effort and cost—fruit growers' net incomes per acre must tend to decline. Cost-saving has a part to play in the process as well, but as every grower knows, 90 per cent of his costs are fixed, and in any one season it is his revenue that determines his profit. In the longer term, close attention to costs might realize economies amounting to £5 to £10 an acre without sacrifice of quality. This sum may be significant to a grower with a large acreage, but is insignificant in comparison with the tens of £s an acre extra that can be earned on farms of any size by raising yields.

The industry-wide aspects of higher yields cannot be overlooked. A high-yield industry would need less land, chemicals and equipment and fewer men than a low-yield industry, and its capacity to meet lower prices for fruit would be accordingly greater. Compare the two situations outlined in Table I, the one based on an average yield of 350 bushels an acre, the other based on an average yield of 250 bushels, assuming the present-day level of costs.

Table I—Estimate of national resources required to produce an average annual crop of 300,000 tons of dessert apples

	at 350 bushels an acre (45,000 bearing acres)	at 250 bushels an acre (64,000 bearing acres)
	£	£
Labour	2,025,000	2,475,000
Materials	1,590,000	2,050,000
Use of equipment ...	728,000	1,115,000
Overheads	910,000*	2,216,000†
Replacement‡	165,000	235,000
TOTAL	5,418,000	7,091,000
Index of aggregate annual cost	100	131
Bushels produced per man—equivalent	3,500	2,485
„ „ per £100 materials	1,000	775
„ „ per £100 equipment cost	2,184	1,426

* average size of holding, 25 acres
† average size of holding, 20 acres
‡ assumed to be one-sixth of the bearing acreage

Unreal as it may seem, the above exercise indicates the type of change with which the fruit growing industry is faced, i.e. to raise the productivity of the resources it uses.

Simple statements of actual picked yields of fruit are quite rightly viewed with suspicion by growers. All yields numerically equal are not of equal worth : matters like size and quality of the crop must also be taken into account. The arbiter of financial success is *net returns per acre,* not yield, and if the Wye Economics Department could present its yield figures in money terms it would gladly do so. Growers as a whole are not yet ready to co-operate in such a salutary experience, however, although many packhouses get out this information for the benefit (and encouragement) of their members.

The grower may perhaps be consoled by the idea that high average yield and high net returns have much in common under modern conditions of production. There are three good reasons for thinking so. First, in a statistical analysis of growers' average prices per bushel—which were kindly made available to the Department by a reputable fruit packing organization—no correlation could be established between yields per acre, and average price

per bushel in 1957 and 1958, which means that average prices were approximately the same whatever the average level of yield. This result suggests that growers who get high yields get the same quality in their fruit—neither better nor worse—than growers who get low yields. There is a delicate point here as to whether the growers with high yields were seeking quality in their crop, and found that their management produced a satisfactorily high yield as well, or whether the same growers were aiming at a high yield and discovered that quality followed automatically.

Secondly, costs per acre vary from farm to farm much less than returns per acre. Production techniques are almost standardized, and the grower with a high marketed yield will have both high net returns and a high margin over costs. Thirdly, the apparently contradictory case of the grower who periodically sets a heavy crop, and then produces predominantly small apples does not obtain high *average* annual yields and so does not come into consideration in this connection. In the light of this situation, the Department has felt justified in pursuing the analysis of financial success through the medium of average commercial yields per acre.

Quality and Yield

Realised price per bushel, then, was found to be largely independent of yield per acre for dessert apples. The exception was the Conference crop in 1958, when high yields—of 400 bushels and more a tree acre—entailed a reduced price per bushel* (the pears coming generally too small). In other words, while it may not be true that a grower at present getting moderate yields who sets out to improve quality will improve yield as well, it seems that the attainment of a high yield involves no sacrifice of quality. Small size, of course, is what marks down fruit ; the amount of skin blemish and lack of colour among samples going into commercial packing sheds are not usually price-limiting factors nowadays. So the practical application of the lack of correlation between yield and price is, that though there may be a liability for colour to suffer a little, lack of adequate size of fruit is not a characteristic of high-yielding orchards. So much for the *general* situation—taking all farms together.

Does a good sample on each farm singly come more often with a heavy crop or a light crop? Growers are divided in their opinions about the answer. Frost-marked *Bramley's* and the like do not enter into this argument, because this issue is between the heavier and lighter variations on the "normal" crop. Growers' experiences will differ in this connection because "quality" has three dimensions : size, colour and cleanliness. Neither a big crop of very clean, but small apples, nor a marked crop of good-sized

* $r = 0.64$: significant at the 1 per cent level.

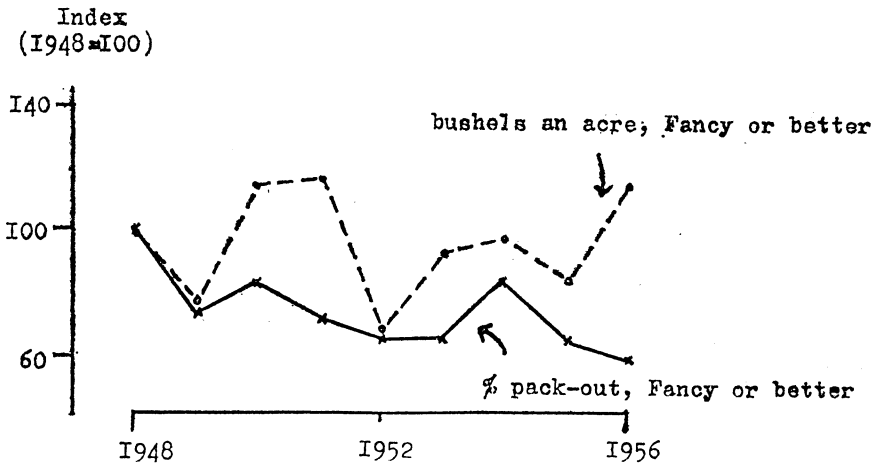
fruits would grade out well. Cleanliness is considered to be more under control than colour, and colour more controllable than size. Growers have different degrees of success in controlling size.

There is a difference in this connection between the crop which is short because the trees have suffered some damage (accidentally low yield) and the short crop which can be explained by the trees "taking a rest" (physiologically low yield). In the first case low yield and low quality will prevail, in the second, low yield and high quality. To look at yield figures with quality in mind—possible only on a small scale as yet—reveals two tendencies. First, that, as many growers believe, the high quality of fruit from "teenage" trees tends to be difficult to maintain during the later life of the tree. Secondly, that for many growers, an above-average crop tends to grade out better than an exceptionally good crop or a below-average one. This theme is now developed by an analysis of yield, quality and pack-out as experienced in one case in practice.

Fruit quality and age of tree

A commercial packhouse of the highest standing has kindly made available to the Department its annual grading results. The packhouse handles dessert apples, predominantly from bush trees now approaching 30 years of age. The mean pack-out figure (Fancy grade or better) of senders' crops over the last nine years has the falling trend shown in the diagram below (the lower, unbroken line ; the upper line records the "Fancy" bushels marketed per acre, and is influenced by a tendency for average yields per acre to be steady).

"Quality" and yield, (I) eleven farms

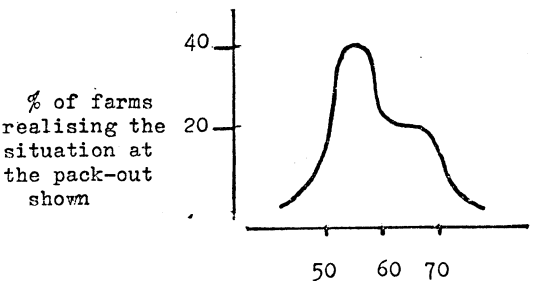


Notwithstanding this packhouse's efforts to maintain a good pack throughout the ten-year period, one must bear in mind that grading standards have become somewhat more severe since price control was relaxed. Even so, it is apparent that the rate of improvement in overall quality, as measured by pack-out, has not kept pace with the market requirement of quality. Had there been fruit from a large acreage of young trees coming in, percentage "pack-out" may have been kept up, but with a static tree population (although the growers were aware of the trend) the effects of age in the trees appear to have been difficult to overcome.

The present analysis is on too small a scale to be convincing, but it seems to demonstrate that, given adequate records, the general relationship between yield per acre and quality on single farms could be established. Above-average yield and normal quality, or above-average quality and normal yield, are two recipes for maximum revenue, given freedom from excessive weather-effects.

Working from experience over the last nine years on these farms, which are subject to common weather effects, it emerges that the above-average crop with normal quality was in most cases the recipe for maximum net returns per acre. Farms' "pack-out" varied between 11 per cent and 92 per cent for single years, but on each farm, the maximum revenue situation was realized at a middle level of quality, coupled with relatively high yield. The frequency distribution of maximum revenue situations in terms of "pack-out" is shown in the diagram below. Most (40%) of the farms were in the best position with a 55-60% pack-out: *average* pack-out of all farms was 53.4 per cent. Presumably, the growers having a pack-out exceeding 60 per cent, but below-average yields ought to try to increase their yields.

The "maximum revenue" situation, eleven farms



This is not the whole story, but it does suggest that what matters to the grower is his "Fancy" pack per acre (i.e. the product of yield x quality). His definite aim should be to make this product as high as possible each year.

On the farms in question maintained yields per acre* have meant that the falling-off in quality has not had such serious effects as it might have had otherwise. The production per acre of "Fancy" grade fruit has not fallen to the same extent as the "pack-out" figures on these farms.

Five statements could clarify the situation as at present known :

(*a*) good yield and high "Fancy" production per acre are correlated†, and are the most desirable combination ;

(*b*) exceptionally high yield is associated with a reduction in overall quality, and with less-than-maximum production of "Fancy" bushels an acre ;

(*c*) exceptionally high quality is associated with low yield (unless the low yield is accidental) ;

(*d*) high "pack-out" and high "Fancy" production are *not* closely correlated‡ (i.e. the same percentage "pack-out" is realised at many levels of yield) ;

(*e*) in other words, high yields entail no sacrifice of quality, but to achieve a high average "pack-out" often entails a low yield.

The falling-off in quality with the approach of middle age in the tree, as reported above, may not be inevitable and may be due to a local cause, such as the chemical properties of the subsoil. In another part of the south-east, a grower having mainly half-standard trees on a light but deep loam has been steadily improving quality since 1949 (see the diagram on page 35). This attribute—of sustaining quality in the crop—may prove to be the most valuable characteristic of what are known as "good fruit soils".

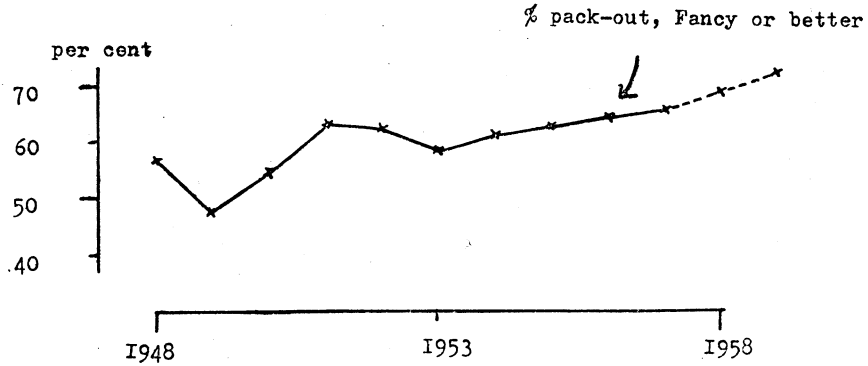
* These farms are not included in the Wye College Yield Census. The level tendency is contrary to general experience. and could be used to support an argument for the value of a field technical staff to growers associating for marketing.

† $r=0.745$: significant at the 1% level.

‡ $r=0.43$.

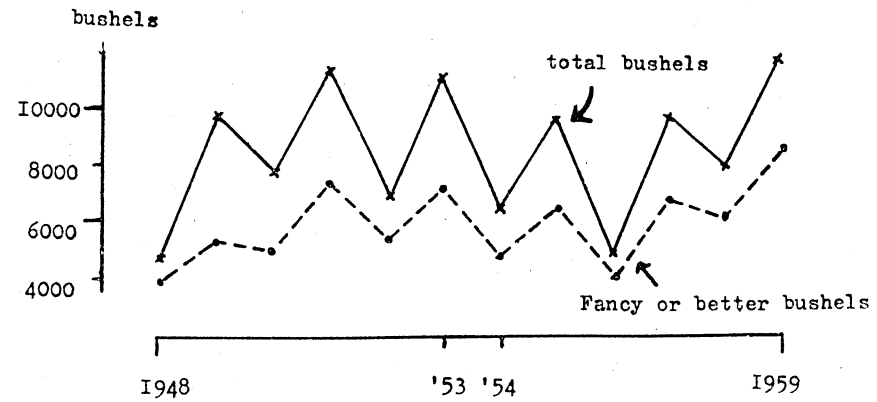
% pack-out to Fancy grade or better—one farm.

"Quality" of crop, one farm, I948-58



It has been this grower's experience that the big crop packs out less well than the lighter crop, but the production of "Fancy" or better fruit is highest when yield is highest. This is not the different state of affairs from that previously described that it seems to be at first: because although production is more biennial on this one farm, there is less difference in terms of actual bushelage between the big crop and the light crop—cropping is on the whole more even. Again, maximum production of "Fancy" or better fruit coincides with a pack-out of about 55 per cent. In contrast to the previous case, however, this farm is tending to raise its "quality" production by growing less fruit but improving pack-out relatively more. Incidentally, the high yields of 1951 and 1953 were not repeated on this farm until 1959.

"Quality" and yield,(2) one farm



Many good growers would be inclined to say that present levels of yield are a compromise—that they are satisfied that present yields are not maximum yields, but that if yields were pushed up higher, it would be at the expense of quality, particularly colour. This would be all right if the underlying trend with age was towards a naturally increasing yield. Reluctant as he may be to accept it, the grower has to face the fact that, with modern root-stocks and quick development of the crop in association with modern, light methods of initial pruning introduced after the tree has become mature, yields having maximum market quality come early in a tree's life ; thereafter it requires an effort on the grower's part to overcome a tendency for net returns per acre to fall off in later life, apart from any change in prices that is occurring.

One way to higher yields per tree is to have a more compact form of tree than is popular today. What is lost by increasing both bud-occurrence density and the " tightness " of the tree, if leaf/bud ratios remain unaltered, is largely a matter of poor colour on the centrally-borne apples, and this is not a point of the highest economic importance if these apples are additional to an otherwise good crop of average quality. It may even happen that a grower will begin to produce more than one type of apple, having some fleshy fruit for early sale, some firm fruit for store, and some " cheap " fruit with which to widen his market.

YIELDS FROM MATURE TREES WERE NOT INCREASING

What is the natural trend in yield ?

Although experienced fruit growers may not share this idea, it is commonly supposed that the trend in yields of fruiting trees can be described as having the form of a flattened arc—i.e. a slow rise (after an initial period of sharp rise) to a time of maximum yields somewhere in middle life, followed by a slow decline and a rapid termination. In such circumstances yields per acre of dessert apples and pears would be tending to rise at the present time. Most trees have not yet reached the assumed period of decline, and as they expand in volume they must surely give the grower an increasing harvest for substantially no increase in work, at least before picking starts. The grower would be in a happy position if this were true. Unfortunately, it has not been true of the last ten years, and it is reasonable to expect that if there was an upward surge in yields, it would become evident over a span of ten years.

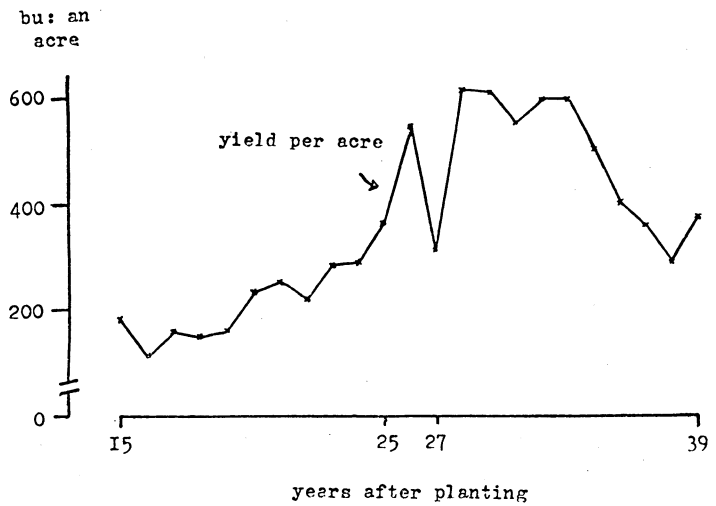
Observers better informed than the layman might well have the same opinion about the natural trend in yields. Has not the fruit grower now got balanced manuring, a clean tree, relief from sulphur-depression, and renewal pruning, to boot? The evidence of the yield records seems to be that these technical improvements, singly or in combination, do not give *sustained* or progressive increases in yield. Each year's average yield in relation to the ten-year average yield is shown in Figure 5 (page 52).

It is urgent that a trend in yield for the bearing life of a tree be delineated soon, because on this one feature hang many of the decisions governing policy on the fruit farm. In the forseeable future, labour costs will continue to increase, and unless yields per acre have a natural tendency to increase too, fruit growers are going to have to think more furiously than they expected. With the conventional form of tree, growers have in any case to reckon with thinning-out, and if yield per acre does not increase towards the middle life of an orchard, one avenue of relief from the inexorable pressure of costs on prices is closed. The alternatives for the grower are (*a*) either to expand acreage slightly, to take up "slack" in resources as their productivity increases, and so increase the output per man, or (*b*) to replace trees early, before yields either begin to diminish or become expensive to maintain. (This policy, of course, entails having more acres out of bearing at any one time.) In any case, these decisions are fundamental: they go right back to questions of how to grow fruit.

Two examples of long-term average yields per acre have recently come to the author's notice, and are reproduced below so that the current ten-year span can be seen in a longer-term setting, and the trend over the whole period of life of particular orchards can also be seen. In both cases, annual yields have been expressed as a moving four-year average.

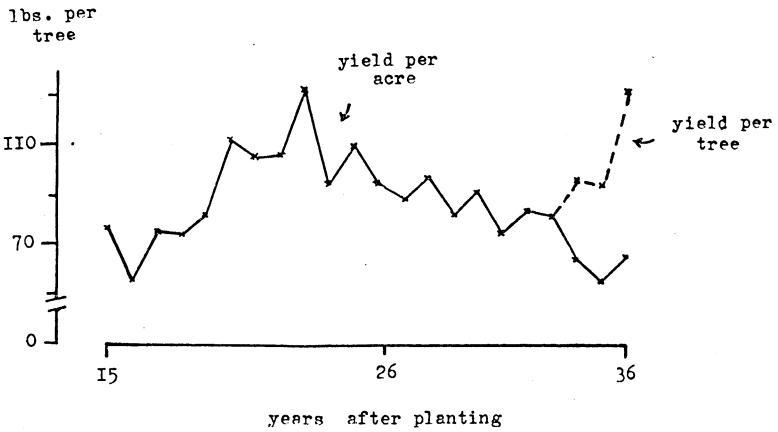
Example I. Forty acres of standard trees, on crab stocks, mainly Bramley's Seedling. In this case, thinning-out and frost have given rise to a marked downward trend after 33 years of age, including only ten years of high cropping (see below).

The course of yields: culinary apples, standard trees, crab stocks



Example II. Conference on Quince A at East Malling, as reported by Rogers and Booth* in the Annual Report for 1958. This was offered as an example of *irregularity* in bearing, but it also may be significant that yields during age 15-25 years were increasing (in spite of four frost years) and that after age 23-25 years came the turning point, and a downward trend set in, accelerated by thinning-out the trees (see below).

The course of yields: pears, bush trees, Quince A



A. P. Preston, writing in the *Journal of Horticultural Science* (January, 1958) quotes maximum yield periods for trees of *Lane's Prince Albert* on different rootstocks, as follows:

Rootstock	Age of tree at heaviest annual yield
M IX, M II	33 years
M IV, M I, M XVI	27 years
M VII	16 years

In most instances, the time of maximum yields came earlier than would be usually anticipated.

It is the natural order of things, therefore, for yields from dessert orchards planted in the late 1920's and early 1930's to begin a declining phase within the next decade, on some soils if not all. The majority of culinary apple trees, too, being considerably older, are in a declining-yield phase as well.

* Bulletins for Fruit Growers: *Irregular Cropping of Pears.*

Dr. S. P. Pearce, the statistician at East Malling Research Station, has given the writer his opinion that the course of yields in many mature orchards is downwards for periods of four to five years, broken by rises after the grower has taken corrective measures. This type of short-term curve might be conveniently described as "inverted saw tooth" and is compatible with the longer-term "flattened arc" or "plateau" concept for the whole life of the tree. Presumably the Economics Department will be in a better position to report on this question in 1970 ; for the present, the evidence seems to suggest that this short-term behaviour is more characteristic of later life of the tree than of early life.

Failure to rise was widespread

It is perhaps too much to say that yields per acre were falling, but it is not too much to say that there is no evidence that average yields were rising. On the evidence presented by the 67 farms:

(i) average yields per tree acre in the second half of the ten-year period, 1952-1957, were lower than in the first half of the period, 1948-52 (although 1948 should have been one definite "off" year) ;

(ii) highest yields per tree acre of most varieties in any one year, on trees over 17 years old, were realised *before* 1953;

(iii) very few farms, in the writer's experience, had higher yields in 1958 than in 1947 *from the same plots* of mature trees. (Both years are technically out of the period now reviewed, but each was the best year of its decade.)

Nation-wide average yields per fruit acre must, of course, have been falling recently because of the increasing acreage of young trees coming into bearing. The Wye College yield figures suggest more than this, i.e. that on a large part of the matured orchards, taking into consideration trees between 17 years and 60 years old, annual yields per acre are not rising. Some of the known reasons for this trend are given below.

Bramley's Seedling. A declining-yield situation is understandable for culinary apples. As growers will be quick to point out, yield is not everything—quality (size) is equally important. Many big growers of *Bramley's* have had deliberately to sacrifice numbers of fruits for the sake of larger, more accessible and cleaner fruits. There has also been widespread thinning-out of trees recently.

Worcester Pearmain. There are still thousands of old trees of this variety, and their senescence could conceivably depress average yields in the way previously noted. The same argument could be applied to varieties like Ellison's Orange and Beauty of Bath. Laxton's Fortune and Lord Lambourne may be examples of varieties which are still too new for the same trend to be discernible.

Cox's Orange Pippin. This is the variety on which the whole art of the fruit grower is lavished, but it still proves "shy" of improvement in yield. Growers are on different *planes* of yield, of course: but on no plane is there evidence of a rising trend over the last ten years. Numbers of 18-year old trees joined the Yield Census orchards each year, and according to present knowledge, their advent should have tended to raise average yields per acre in recent years.* Yields of long-established *Cox* orchards have not increased either. It may be, however, that yields have *steadied,* which is valuable in itself. *Cox,* for example, has a high regularity coefficient and has been the most consistent of the old varieties grown on a large scale.

"Failure to rise" may be just another way of saying "maintained", but is "maintenance" of yield good enough for the future progress of the industry?

A glanch· at Figure 5 (page 52) will show the movement in yields over the last ten years. In this diagram, yields are shown to be high or low relative to the mean (average) yield for the period. To take dessert apples, only in two years since 1952 has yield per acre been above the mean, and never on the same scale as in 1950 and 1951: 1956 was a particularly poor year. As regards culinary apples, much the same holds true, with three years of alternating and increasing deficits. Pears present a more sober picture after 1949 and 1950, but were well "up" only once in the last five years (in 1955).

As if the above were not enough, there is more evidence of a considerably more serious character. Any trade or profession has its experts, and fruits growing has its "kings"—"good growers" who set cultural standards and technical methods for the industry. Yields of the two main dessert varieties on the ten most consistently high-yielding farms have been extracted and are shown below:

Annual average yields, bushels per tree acre, ten best growers, 1948-57

	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Cox's	279	362	412	423	451	357	432	317	224	303
Index of 5-year production:					1948-52=100			1953-57=108		
Worcs.	481·	448	529	564	439	668	545	674	335	431
Index of 5-year production:					1948-52=100			1953-57= 86		

* This is not the same situation as 8-year-old trees coming into cropping for the first time.

The widespread use of the Malling range of rootstocks and the constant rise in minimum quality standards have obviously affected the whole course of fruit growing in a very radical way. Previously, a grower had been able to look forward to yields increasing with age: now, although the smaller, lower tree is more in tune with the times, the grower has not such comfortable expectations.

Probably the most thorough orchard surveys ever carried out were those emanating from Cornell University in New York State between 1905 and 1910. Then, when outright yield was all that mattered, trees at 40 ft. apart on good soils were quoted as giving maximum yields at 50-65 years of age ([1, 2]); trees on inferior soils bore maximum yields at age 45-50 years ([3]) (1905 report). Even in 1930, highest average marketed yields per acre were picked from trees of 60-69 years old ([4, 5]).

TOWARDS A THEORY OF ANNUAL YIELDS

Fruit growers still lack the guidance of a theory of yield: why and how yields on single farms vary so much from year to year has never been fully or satisfactorily explained. The present position is that changes in annual aggregate or national yield per acre can be accounted for, if not forecast, whereas changes in the annual yield on one farm, on even on one block of trees, cannot often be accounted for.

Theory of aggregate yield

In any one year, the prevailing level of average yield in Britain is a function of the "set" of fruit. The following factors have a share in determining what the initial set will be, and how much of the set fruit hangs till harvest time:

(*a*) weather conditions at pollination time;
(*b*) the blossom condition—whether "off" or "on";
(*c*) weather conditions between fruit set and harvest;
(*d*) the elapsed time since the last big crop.

In years like 1947 and 1958, when the national crop reaches a peak, most (but not all) trees in regular bearing have an above-average crop. It is the irregularly-bearing trees which have unusually high yields and have caused the excess, not trees which have a high *average* yield—the latter do not respond to ideal conditions in anything like the same degree as the irregular trees. This condition merits some explanation. It seems to be the case that in the years of highest production, many more trees set a crop *unaided* and are able to carry a crop through to harvest, than in the years of normal production. If this is so, there would seem to be grounds for thinking that better management (e.g. use of aids to fruit-setting) and measures to increase the stored reserve of energy in the tree could lift and make more regular the "occasional" trees.

The additional supplies from these irregular sources are probably greater in volume than the *additional* supplies forthcoming from regularly-bearing orchards, and are the unbalancing factor in marketing. The higher the yield of a *regular* orchard, the less likely is it to be subject to increase in an exceptionally favourable year.

In any year, flower formation on all apple trees other than those of biennial varieties in a distinctly "off" year, will suffice to produce a good crop of fruit if other conditions are right—only 50,000 "settings" an acre are required. When, as in 1958, there is protracted moist and mild weather for pollination, a heavy set will ensue: if there is no frost damage and *if* the weather subsequently does not put too high a physiological overstrain on the trees, and *if* the tree has had a good rest since its last big crop, the full crop will endure (on the irregular tree) till harvest time. These conditions seem to be realized about once in every ten years.

Theory of individual yield

The above account is inadequate for the individual commercial grower who wants a fair crop every year, and whilst a complete theory is not yet attainable, in moving from the national yield to consider the yield on individual farms there is first of all a change of accent to be made: weather enters less into consideration, and management of the trees becomes correspondingly more important as a determining factor.

Management practices. An explanation of the effect of management on yields on individual farms is best attempted in two parts. First, why there are differences in level of average yield from farm to farm; secondly, why there are variations at all levels —sometimes wide variations affecting varieties not thought to be biennial in habit—from year to year.

Level of yield. Average *yields per acre* for each farm, such as the Department obtains from growers, amalgamate of course different levels of yield of the same variety from differently-constituted orchards on the same farm. Rootstock, tree spacing and age all have their effect on yield. For this reason, attention is confined here to yields of Cox's Orange Pippin, the trees of which are more alike in age, distance apart and rootstock, than any other variety.

There is evidence of the efficacy of the practices recommended by technical advisers, in that the ten growers with the highest ten-year yield of *Cox* were all following similar practices, although adapting them to their own unchangeable circumstances. Those practices were:

pruning—renewal system, or modifications thereof;

manuring—4-7 cwts. nitrogenous artificial fertilizer per acre in two applications,
1½ cwts. potassic fertilizer to balance,
1 cwt. phosphatic fertilizer,
occasional organics.

spraying—no winter wash: previous reliance on sulphurous formulations has given place to Captan in the last five years;
low volume automatic application; up to 14 washes a season;

sward management—kept short by blade-mowing, occasional breaking-up envisaged;

rootstock—M.II.

pollinator ratio—1 in 9 highest: 1 in 3 lowest;

soil type—sandy loam or medium loam;

elevation—between 100 ft. and 250 ft. above sea level.

All the ten growers mentioned above recorded yields exceeding 290 marketed bushels a tree acre of Cox's over the ten-year period 1948-1957. Other growers, *including some in the same favourable locality* as several of the "top ten", were following the same practices but getting lower average yields. And even among the top ten, the ten-year average yield ranged betwen 292 and 415 bushels a tree acre. The situation here is that growers are adopting largely uniform practices and getting highly variable results in terms of yield of fruit. Why should this be so?

No one knows what the natural, irreducible variation in fruit trees of different origin, possible due to genetical differences, is, but is it likely to be as high as ± 17 per cent?* Experience in the field suggests that it is not, and some of the difference in average level of yield in high-yielding orchards is due to management factors. In short, when all cultural practices have been near-standardized, the actual bearing area of trees, the size of tree, the form of branch system, and the "tightness" of the tree are not common to all orchards and can account for perhaps 10 per cent of the variation in average level of yield. All these are environmental factors as far as the actual *propensity to bear* of the tree is concerned.

Tree size. Many growers reported that yields per acre of dessert varieties after thinning-out were rarely as high as previously. Economy of harvesting, too, cannot be overlooked. Apples carried 15 ft. above the ground are less valuable than identical apples carried 5 ft. above ground; this works to the advantage of smaller trees, which in any case seem to be the best recipe for high average

* This is the deviation of the highest and lowest average yields from the mean of 353.5 bushels per tree acre.

marketed yields. Cox's trees giving highest yields per acre (at 20 to 25 years old) were remarkably uniform in size, having a mean span of about 18 ft. and a mean height of 16 ft., although some blocks of trees of 13 ft. span and some blocks of trees of 22ft. 6in. span must be included among the most productive.

Tree form. Trees having a main framework of less than six branches were less productive than most others, the common number being between 8 and 12. Blocks of open-centre trees having a very short leg, where developed as a "funnel", were not among the highest yielders: similarly, to prune to an inverted cone, or outwardly-inclined ring of fruiting branches around an empty centre tree on a normal leg, also seemed to detract from yield.

Highest sustained yields per acre were obtained where the trees were filling up the space in the orchard, each tree being relatively compact, having the middle filled but not overfilled with short branches, and being equally furnished all round with bearing wood. Where yields were not of the highest, trees were often "light" of wood over as much as half their circumference.

Annual variations

In *Cox*, as in other varieties, the ups and downs in yield per acre are particular and not general. It can hardly be believed that the variations in micro-climate are as great as the variations in annual yield.

The extent of the variations experienced will probably stagger most readers. All too clearly, the size of the crop in any year is made up of a number of successes and a number of failures on farms, and it only needs a sustained significant reduction in the number of failures to ensure a much-increased annual crop. This would seem to be a much more economical method of producing more fruit than planting up new orchards. In fact, among the ten best growers (in terms of *average* yield) the actual change in in crop from year to year, on a crop averaging 353.5 bushels a tree acre, was no less than 165 bushels a tree acre—almost 50 per cent. In other words, on average, the change on these most successful farms was between a crop of, say, 270 bushels a tree acre one year and 435 bushels the next year.

The distribution of variation was as follows:

three growers had an annual variation of less than one third of their average crop;

three growers had an annual variation of between one third and one half of their average crop;

four growers had an annual variation of between one half and two thirds of their average crop.

Do these figures give any measure of the size of this problem, which has hitherto escaped its due notice? As has been said often enough previously, all farms are not "up" and "down" in the same year: the opposite swings on individual farms tend to cancel each other out. Size of orchard *per se* appears not to have any effect upon regularity of bearing: the two farms with the lowest co-efficient of annual variation have less than one acre and more than ninety acres of Cox's. Pollinator ratio seems to have little effect: growers with a 1 in 9 ratio were experiencing variation co-efficients as low as 16 per cent and as high as 65 per cent.

Nevertheless, there are exceptional cases of very level bearing. Here is one example of regularity:

Yield per tree in bushels, 1.5 acres Cox's Orange Pippin, 1953-59

1953	1954	1955	1956	1957	1958	1959
4.3	4.3	4.5	3.1	5.1	4.9	5.4

In this case, the annual yield seems to be largely independent of weather influences, because there has been quite a range in weather conditions at fruit-setting time in the last seven years. And, contrary to general experience, yield which was already high in 1953-4, is tending to increase.

There is evidence in the above figures of an induced disposition to regular bearing. It could have been achieved by setting more fruits than were necessary to give the yield recorded and then thinning the fruitlets to a number which, either accidentally or on purpose, was sufficient to give a high yield and also to ensure the leaf/fruit ratio upon which the differentiation of adequate fruit buds depends. As it happens, the regularity of yields recorded above was obtained without fruit thinning in any year.

To the writer's knowledge, no systematic studies of the cycle of (a) fruit bud density per foot of bearing wood; (b) proportional fruit set; (c) proportion of fruit retained; and (d) size and weight of fruit harvested, have been made. In view of the tendency to declining yields in bush trees, it may be that either bud density per foot of wood, or actual bearing area per acre ceases to expand after a given point under some modern pruning systems.

It seems to the writer that the pioneer work of Harley and others (6) in the U.S.A., in the early days of World War II, regarding the differentiation of fruit buds has not been given the commercial testing it deserved. If these workers' precepts hold good, a fruiting tree should not lack fruit bud in any season, and once this desideratum has been acquired the succession of adequate blossom, good fertilization, retention of sufficient fruitlets and their subsequent growth to market size can follow, up to the known capacity (vigour) of the tree. This subject of the *capacity* of a tree

is worthy of further study. Although no examination of this question has been made so far in connection with the yield enquiry, it has become clear that the *capacity* of a tree to bear fruit is partly within the control of the grower, in the sense that he can control within limits the area of bearing wood, and density of spurs, that he will carry. Could observational studies of spur density and so on be followed up by counts of the proportion of buds "set" in relation to the number present, the proportional retention of fruitlets and the grading of the picked crop, growers would begin to see what "capacity" meant.

The excessively-open-centre form of bush tree is already under something of a cloud, and the bush tree as such may prove not to be the most economical tree form. A bush-tree plantation does not "settle down" for long in any given state, and no spacing is the "ideal" for many years together: the optimum spacing is a matter requiring nicety and speculation in its calculation. Pruning requirements increase as the trees expand; then, at one stage, the number of trees is cut by half, and balance that has been arrived at between the labour available and the yearly tasks, is destroyed. In principle at least, the standard, contained, unvarying space of the Pillar tree has a lot to recommend it, and it promises to give, over a long term of years, more fruit than a bush tree for each hour of labour expended on it.

Finally, the belief is gaining ground that the prevailing weather conditions during the blossoming season are not necessarily largely responsible for the size of the crop on a particular farm later in the same year. There are far too many instances of the weather theory being frankly contradicted in practice. In the absence of a severe late frost, the cumulative effects of matters like the size of the previous crop, the weather in the preceding year, the pruning of the tree, chemical balance in the cells of the young wood, the water economy and food-reserve status of the tree, can have a considerable effect on yields. If the tree is ready, even slight or intermittent activity of the normal pollinating agents should suffice to set a normal crop.

What this theory suggests in the way of response from the grower is that he should concentrate his attention and operations more on the early part of the season, when the crop is forming, in an endeavour to set more apples (in most years) than he wants to keep, and then, by judicious thinning of fruit, and later by pruning, to recreate the means of keeping the cycle going.

REFERENCES

1. Warren, G. F. Cornell University Agricultural Experiment Station Bulletin 229 : 484 1905
2. Warren, G. F. do. Bulletin 266 : 311 1905
3. Cummings, W. do. Bulletin 262 : 289 1909
4. McDaniels, M. and Heinicke, L. do. Bulletin 497 :3193 1929
5. La Mont, T. E. Fruit Farm Management Cornell Extension Bulletin 219 1932
6. Harley, Magnes, Masure, Fletcher and Dagman. U.S. Department of Agriculture. Technical Bulletin 792 1942

Fig. 2. Ten Years' Yields.

Average annual yields of six dessert varieties of apple, 1948-57.

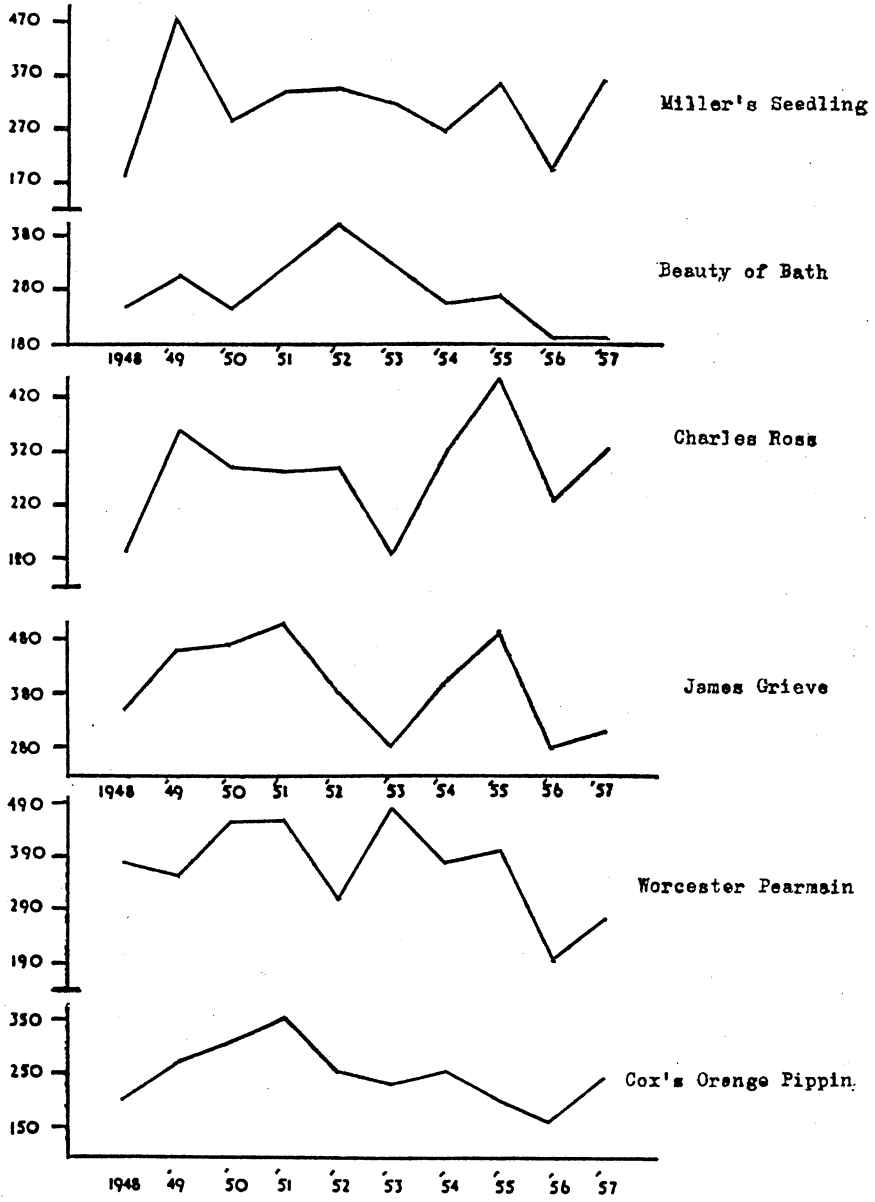


Fig. 3. Ten Years' Yields.

Average annual yields of four culinary varieties of apple, and two pears, 1948-57.

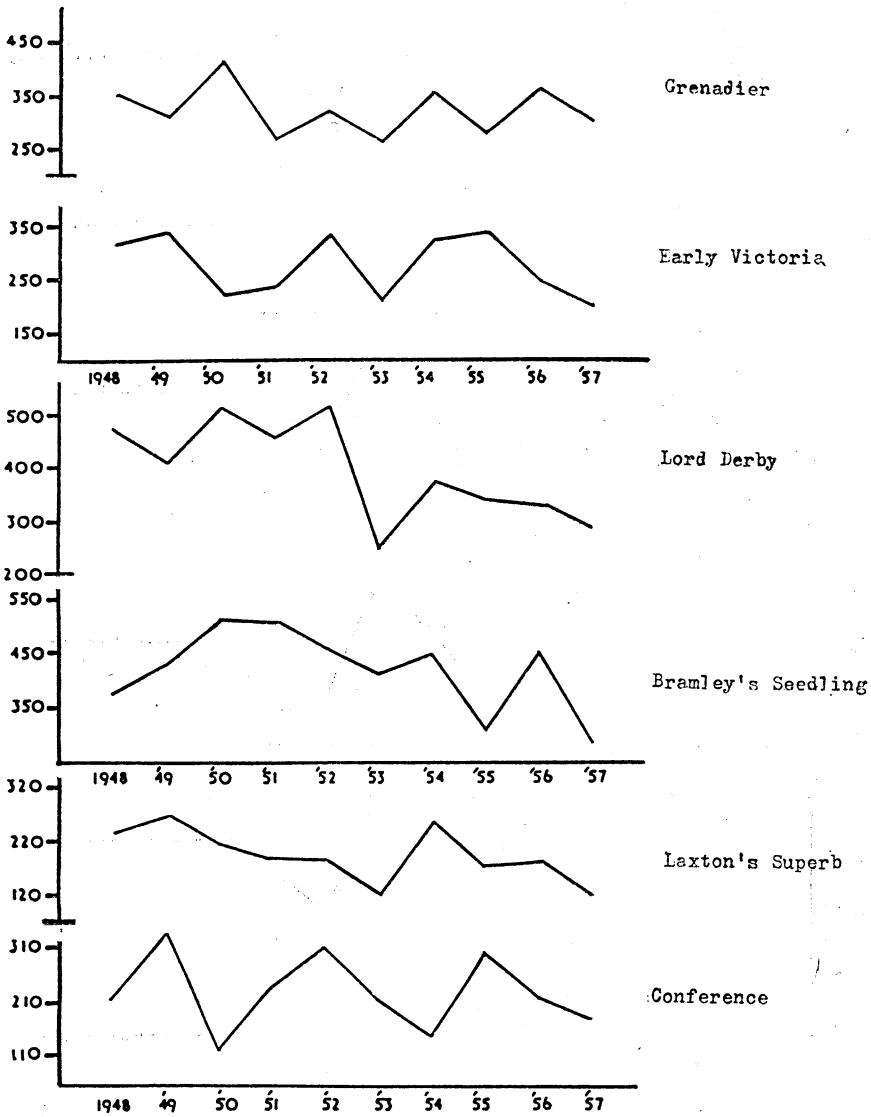


Fig. 4. Distribution of Yields (bushels per tree acre) 1948-57.
Five leading varieties of apple and pear.

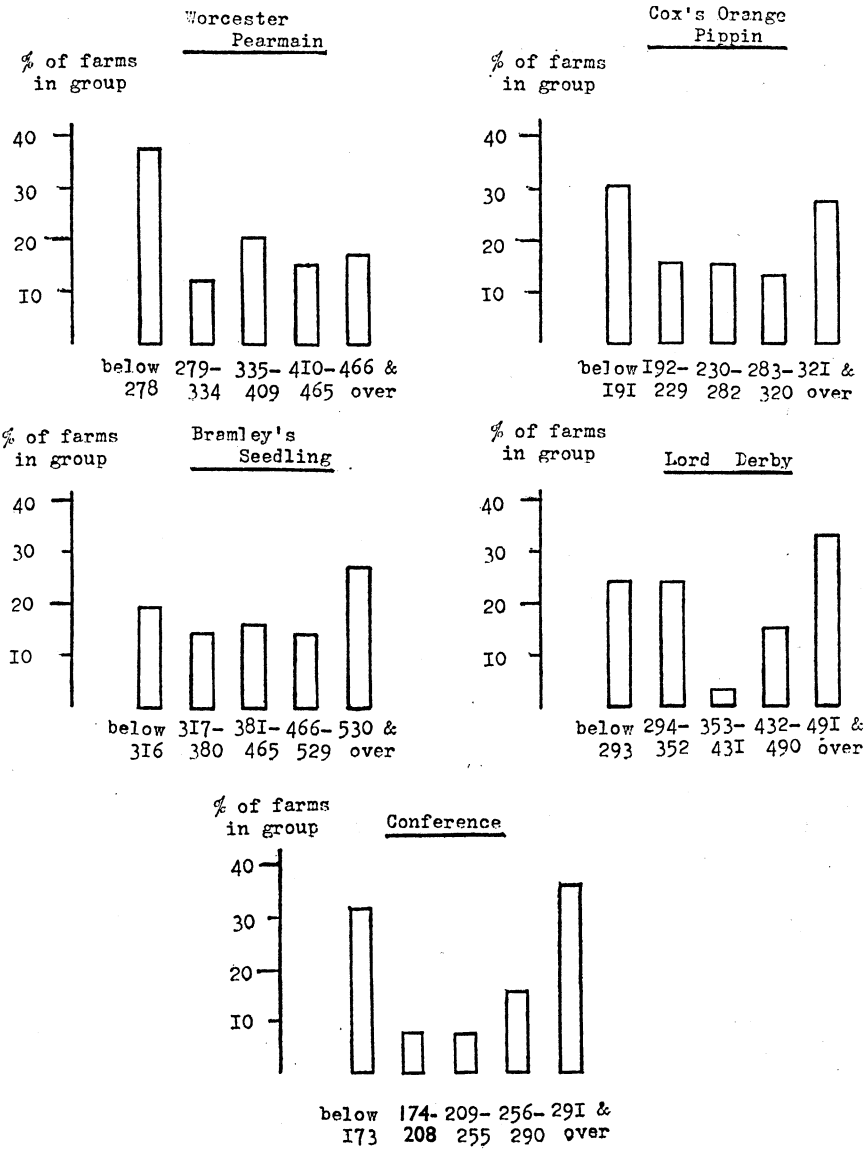
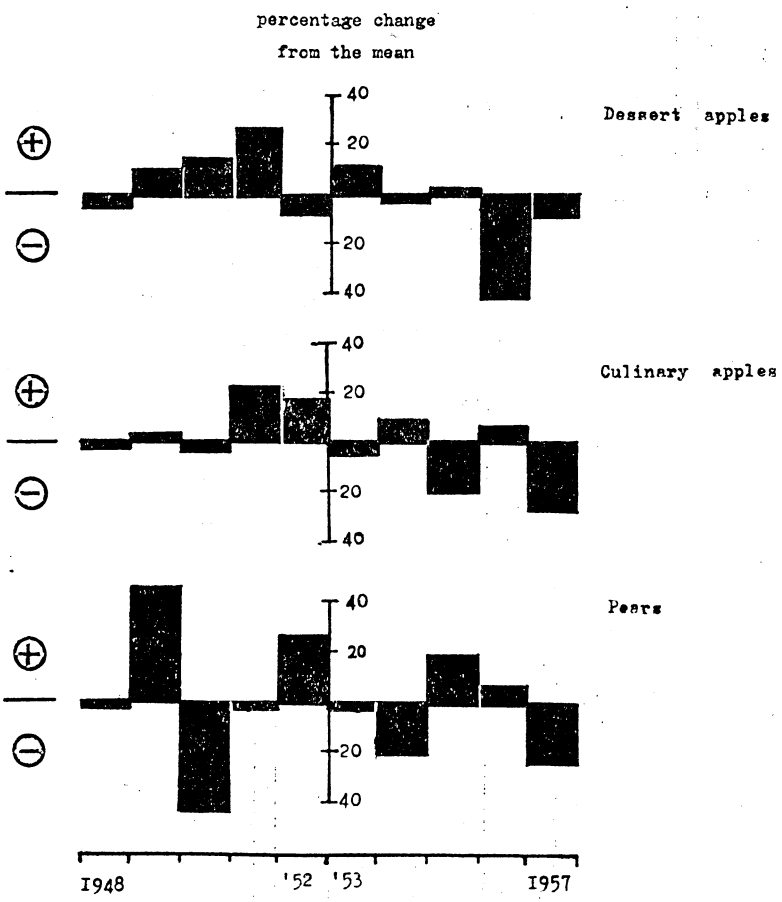


Fig. 5. The Course of Yields, 1948-57.
Average annual yield per tree acre in relation to the ten-year average yield.



DESSERT VARIETIES OF APPLE—YEARLY YIELDS, 1948-57

bushels per tree acre

	No. of Records in Sample	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
James Grieve	9	349	463	467	518	398	292	410	517	289	319
Worcester Pearmain	32	389	356	459	459	307	482	380	416	196	280
Ellison's Orange	9	203	275	372	305	326	391	293	375	256	376
Miller's Seedling	15	178	486	286	340	347	324	270	360	185	362
Charles Ross	9	136	367	298	283	366	121	326	460	231	337
Beauty of Bath	19	245	311	249	329	403	334	262	278	185	186
Laxton's Superb	15	169	364	140	379	157	410	248	448	145	294
Cox's Orange Pippin	26	195	269	301	352	261	236	277	218	177	273

CULINARY VARIETIES OF APPLE—YEARLY YIELDS, 1948-57

bushels per tree acre

	No. of Records in Sample	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Bramley's Seedling	44	380	429	522	512	466	414	450	305	466	287
Lord Derby	23	467	409	501	456	503	242	370	346	338	286
Newton Wonder	26	376	298	506	476	554	368	439	294	314	228
Grenadier	19	350	308	417	262	312	249	356	279	360	296
Early Victoria	5	317	339	222	235	335	209	323	333	242	196
Lane's Prince Albert	8	209	282	201	272	248	255	188	315	75	123

PEARS—YEARLY YIELDS, 1948-57

bushels per tree acre

	No. of Records in Sample	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Dr. Jules Guyot	9	384	355	343	239	482	412	298	160	289	156
Doyenne du Comice	7	202	526	44	290	262	189	300	269	358	277
Conference	14	222	340	111	240	314	240	145	312	212	179
Laxton's Superb	8	246	274	222	198	197	126	262	185	217	139
William's Bon Chrétien	7	204	289	46	132	264	91	288	212	288	117
Fertility	6	143	244	106	135	206	221	251	175	209	216