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Orchard Efficiency Analysis in Mangoes (*Mangifera Indica* Linn.) and Oranges (*C. Sinensis* Osbeck)

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Introduction. The Presidency of Madras is reputed to be one of the leading producing centres of mangoes and sweet oranges. According to the latest figures (2) the province claims an area of 244,945 acres under mangoes with a marketable production of 20,000,000 railway maunds of fresh fruits, of which 400,000 railway maunds are exported annually to other parts of India. Although the sweet oranges comprising mainly of two commercial varieties viz., the Sathgudi and Batavian account to-gether at present for a production of 195,000 railway maunds, about 65% of the orchards under these two varieties are yet young and have not reached the bearing stage.

An outstanding feature of the mango production in this part of India is that, it is not the result of a few standard commercial varieties but of a vast number of distinct horticultural entities, many of which constitute nothing more than mere local curiosities. In the Ceded districts, although a very large number of varieties are under cultivation, those that are extensively grown, are Neelum, Bangalora, Mulgoa, Andrews, Baneshan, Khader and Peter. It is gradually being recognised that efficiency of production and marketing requires that the orchards should be stocked with a limited number of economically profitable varieties instead of the prevailing multiplicity of varying forms and types of good or indifferent value. Information on the commercial value of each of the various varieties is, therefore, being increasingly sought for, especially for the raising of new plantations.

In the case of sweet orange plantations, however, seed propagation has been the rule in South India till very recently. It is in the very nature of seed propagation, that the plants raised become extremely variable, so much so that it is found impossible to obtain a standardised crop from any single plantation. The promiscuous crossing that takes place in nature between conjugally compatible varieties and species of citrus, have led to the origin of numerous and varied types and forms, so that the efficiency of orange production is found to be fast undergoing a process of quality deterioration. However, the polyembryonic nature of sweet orange (6) and the consequent origin of large number of apogamic seedlings identical to the seed parent has possibly served as a check in this down-ward march of the South Indian orange industry.

Hodgson (3) has pointed out that the factors governing successful production of fruits of any of the varieties depend primarily upon the environment, cultural practices and inherent character of the trees. In a crop like mango, which hardly receives any cultural attention in the Ceded districts after the trees attain the bearing stage, and which does not seem to afford much scope for improvement of cultural pratices at the present stage of low

orchard returns, the possible improvements that can be effected appear to lie primarily in the direction of stocking the orchards with inherently highly productive and choice fruiting trees of economically profitable varieties. Such a step will also be obviously necessary in the case of sweet orange plantations, especially in view of the very wide variation in orchard returns from plantations located under apparently identical conditions

As a means of visualising the relationship between orchard productivity and inherent bearing capacity of the trees and varieties, separate investigations dealing with mangoes and sweet oranges were initiated at the Fruit Research Station, Kodur, during 1936 and 1937, respectively. The results presented in this paper relate to the data collected for these investigations during the period of four years in the case of mangoes and three years in the case of sweet oranges.

Materials and Methods. A private mango grove at Kodur covering an area of about 50 acres and containing 1632 bearing trees of 25 different varieties was selected for one of these investigations. For the study with sweet oranges, two separate sathgudi (syn. chinee orange) orchards, close to the Fruit Research Station, Kodur and located at a distance of about 440 yards from each other, and consisting of 212 and 102 seedling trees respectively of uniform age and in full bearing condition were selected. The former orchard has been designated as No. 1 and the latter as No. 2 in this paper.

The performance records of individual trees in these three plantations were estimated according to the lines suggested by Hodgson (3). Briefly, for the purpose of recording data and analysis of the results the system adopted consisted of the arbitrary fixing of four classes of trees according to relative production, taking the normal full crop for the year as the standard. The numerals 1, 2, 3, and 4 were used to designate heavy, medium, poor and no crop-production respectively. In the case of mangoes estimates of flower production in the case of each tree were also made and recorded similarly.

Since a number of trees in the mango plantation consisted of weak or diseased individuals, it was felt necessary to include for the purpose of analysis only such trees as were of apparently uniform vigour and growing as close together as possible in compact areas. In all, 434 Neelum trees in 5 separate plots, 630 Bangalora trees also in 5 different plots, 41 trees of Andrews variety in one plot and 38 Mulgoa trees in yet another plot were finally selected for the purpose of analysis. The specimen records from a Bangalora Block plot are given in Fig. I. Such a necessity for selective analysis was not felt in sweet orange plantations, as almost all the trees were very uniform in vigour and health.

In presenting the data in this paper, the performance of the first and the last class of trees have only been taken into account. This restriction is expected to reduce the error in estimation of performance due to personal factor, to the narrowest limits possible.

Performance Record Chart of Bangalora Block-Y-C. R. Garden, Kodur 1936–39.

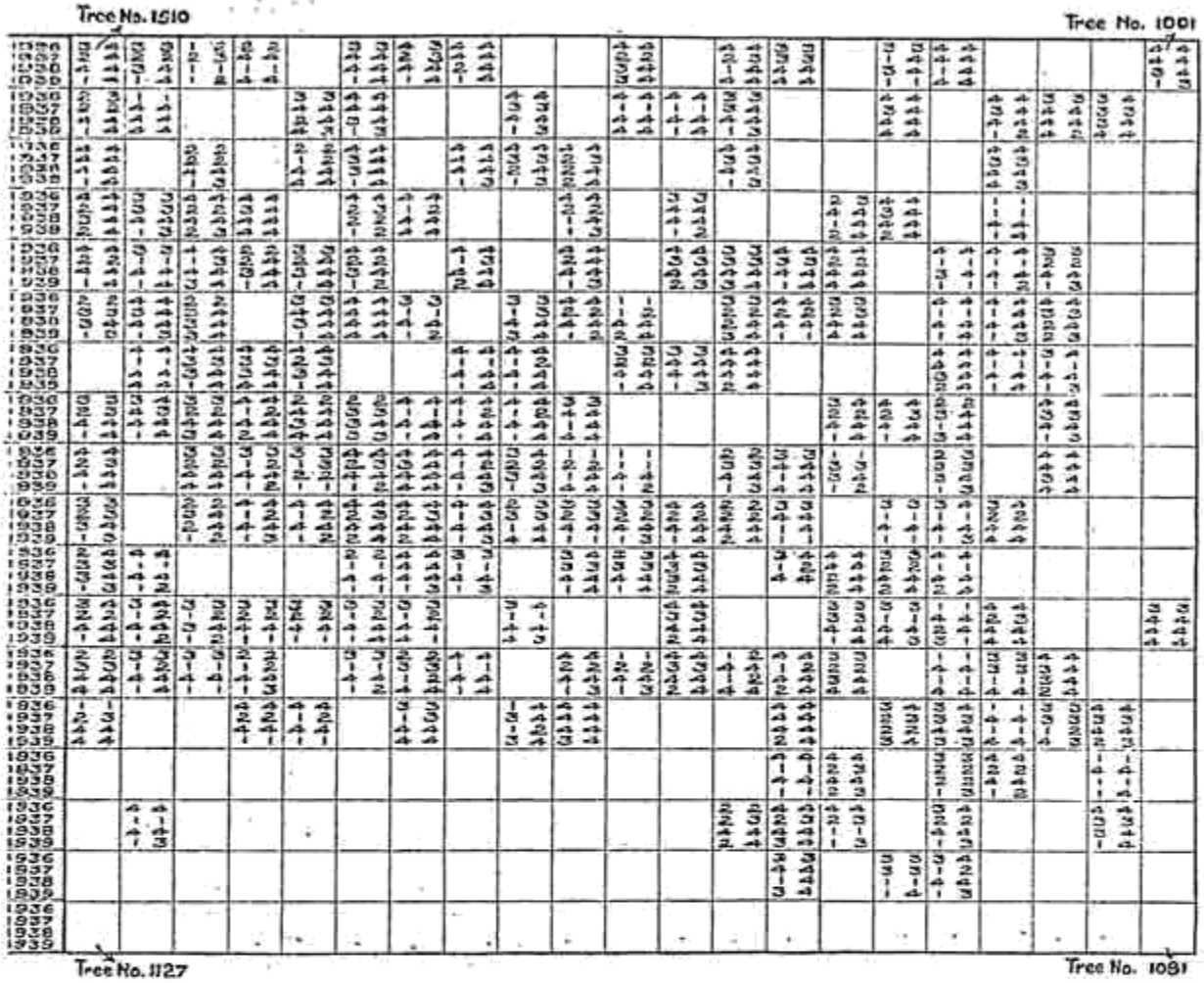

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Figure I.

1. Heavy flowering or fruiting. 2. Medium. 3. Poor. 4. Very poor no flowering or fruiting.

Note. 1. The left hand figures in each square indicates estimated flower records, while the figures on the right stand for estimated fruit yield records for the same tree in that square for the year.

The sathgudi orange is, however, known to bear two main crops regularly in a year in this tract. This feature has rendered necessary to estimate the performance of trees selected for these studies at two different periods of the year, and analyse these data separately for each crop.

Data and Discussion of Results.

1. **Mango performance records.** In statement No. 1 are given the percentages of poor and heavy flowering trees in each of the four varieties under study during 1936–39.

It is seen from the above figures that on the basis of flowering, the percentage of profitable trees has not exceeded in any year 11·7 in Neelum, 49·0 in Bangalora, 14·6 in Andrews and 42·1 in Mulgoa. On the other hand, the percentage of poor flowering trees has been as high as 74·8 in Neelum, 80·2 in Bangalora, 90·3 in Andrews and 93·7 in Mulgoa.

Statement 1. Showing the percentages of poor and heavy flowering trees of 4 varieties of graft mangoes at Kodur. 1936—1939.

Total number of tress: {Neelum=434, Bangalora=630, Andrews=41, Mulgoa=38.

Particulars.	1936				1937				1938				1939			
	Neelum.	Bangalora.	Andrews.	Mulgoa.	Neelum.	Bangalora	Andrews.	Mulgoa.	Neelum.	Bangalora.	Andrews.	Mulgoa.	Neelum.	Bangalora.	Andrews.	Mulgoa.
Percentage of poor-bearing trees	60·6	74·3	90·2	79·0	58.3	43·2	78·8	52·7	70·6	80·2	90·3	93·7	74·8	35·0	66·4	39·5
Percentage of heavy-bearing trees	9·9	8·6	4·9	2·6	15·2	27·8	14·6	10·5	11·7	12·5	2.4	nil	6·4	49·0	9·7	42·1

Statement 2. Showing percentages of low, and heavy fruting trees of Neelum, Bangalora, Andrews and Mulgoa trees during 1936—39.

Total number of trees: {Neelum=434, Bangalora=630, Andrews=41, Mulgoa=38.

Particulars.	1936				1937				1938				1939			
	Neelum.	Bangalora.	Andrews.	Mulgoa.	Neelum.	Bangalora.	Andrews.	Mulgoa.	Neelum	Bangalora.	Andrews.	Mulgoa.	Neelum.	Bangalora.	Andrews.	Mulgoa.
Percentage of poor-bearing trees	63·8	75·7	90·31	87·0	76·7	62·0	90·8	100·0	84·0	92·4	9·5	100·0	32·00	78·0	100·0	100·0
Percentage of heavy-bearing trees	9.0	7·9	2·4	2·6	3·1	9·0	nil	nil	7·1	5·0	2·4	nil	3·2	2·0	nil	nil

When the data relating to the estimated yield of fruits are similarly analysed, the low percentage of heavy bearing trees in the plantation is brought out more prominently, as is evident from statement No. 2.

The above figures show that the maximum percentage of heavy-yielding trees during the four-year period has been only 9·0 in Neelum and Bangalora, 2·4 in Andrews and 2·6 in Mulgoa, whereas the maximum percentage of poor-yielding trees has been 84·0 in Neelum, 92·4 in Bangalora and 100. 0 in Andrews and Mulgoa. An amazingly high presentage of unprofitable trees seems, therefore, a common feature in these four varieties of commercial importance in this tract.

The above data does not, however, represent an accurate picture of the relative economic importance of any ot the four varieties, nor does it indicate the manner in which the varieties react to the popularly believed phenomenon of biennial or periodic bearing in mangoes. For this purpose the data have been analysed separately with a view to trace the performance of each individual tree of all the four varieties during the four-year period. This has furnished an idea of the proportion of trees in each variety that bear an uniform crop of flowers or fruits in two, three or four years during the four-year period. The summarised data are presented in Statement Nos. 3 and 4.

Statement No. 3. Showing the percentages of consistently heavy and poor flowering trees in a two-year, three-year and four-year periods.

Total number of trees ;— Neelum = 434 Bangalora = 630; Andrews = 41 Mulgoa = 38

Period	Consistently heavy-flowering				Consistently poor-flowering			
	Neelum	Bangalora	Andrews	Mulgoa	Neelum	Bangalora	Andrews	Mulgoa
Any 2-year period	6·9	25·4	4·9	5·3	89·2	65·9	95·1	89·5
Any 3-year period	0·2	2·1	2·4	nil	53·9	48·2	85·4	60·5
Any 4-year period	nil	0·1	nil	nil	19·6	13·9	41·4	13·2

Statement No. 4. Showing the percentages of consistently heavy and poor fruiting trees in two-year, three-year and four-year periods.

Total number of trees : Neelum = 434. Bangalora = 630. Andrews = 41. Mulgoa = 38.

Period.	Consistently heavy-fruiting.				Consistently poor-fruiting.			
	Neelum.	Bangalora.	Andrews.	Mulgoa.	Neelum.	Bangalora.	Andrews.	Mulgoa.
Any 2-year period.	3·9	3·0	2·4	nil	94·5	98·7	100·0	100·0
Any 3-year period.	0·5	nil	nil	nil	74·2	80·0	95·1	100·0
Any 4-year period.	nil	nil	nil	nil	35·5	39·5	83·0	84·2

The following inferences are warranted from the above figures :-

(i) There is not a single tree in any of the four varieties that has produced consistently heavy or medium crop of flowers consecutively in the four-year's period under study, with the solitary exception of a Bangalora tree that has consistently borne heavy crop of flowers throughout the four year period.

(ii) On the other hand, the percentage of consistently poor-flowering or fruiting trees during the four-year period has been as high as 41·4 and 83·0 respectively in Andrews, 13·2 and 84 2 respectively in Mulgoa, 13·9 and 39·5 in Bangalora and 19 6 and 35·5 in Neelum. The existence of such a high percentage of consistently non-productive trees is a serious draw-back in the orchard under study.

(iii) The inferences drawn above for the four-year period apply almost in a similar degree to the three-year period also except that in the case of fruiting in Mulgoa and Andrews, the percentages of trees that bore poor crop of fruits consistently during three out of four years have been as high as 100·0 and 95·1 respectively. This surprising fact points out the utter futility of raising commercial orchards of these two varieties in this tract.

(iv) The percentage of consistently heavy-flowering trees in any two out of the four years has been the largest in Bangalora, but this advantage has not been maintained till the fruit ripening period. In fact, the percentage of consistently heavy-fruiting trees in any two years out of the four-year period has been only 3·9 in Neelum, 3 0 in Bangalora 2·4 in Andrews and nil in Mulgoa, while the percentage of consistently poor-fruiting trees in any two years has been as high as 94·5 in Neelum 98·7 in Bangalora and 100·0 in Mulgoa and Andrews.

The above facts clearly indicate that, one of the most important lines of improvement that requires to be effected in the mango industry in this tract is to increase the proportion of consistently productive individuals. Whether this can be brought about by propagation of plants from selected parents of inherently heavy-yielding capacities or by hybridization are questions that merit serious consideration in preference to the improvements that can possibly be effected through orchard cultural practices

That Mulgoa and Andrews are not commercially profitable varieties in this tract has been clearly brought out from these studies. In a separate series of investigations not reported herein, it has been found that Neelum and Bangalora possess the longest marketing season and Mulgoa has a very low percentage of perfect flowers in the panicle, which results in its shy-bearing habit. A study of the prices realised by some of the important varieties during a period of six years (1931—1936) has also revealed that, as against an average of Rs. 6 per basket received for Mulgoa and Andrews during the height of the season, Neelum commands a price of as much as Rs. 10 per basket towards the close of the season, when fruits of the above varieties are scarce, even though during the mid-season the price may range from Rs. 1—8—0 to Rs. 3 per basket. The relatively higher and regular bearing tendency of Neelum, its longer marketing season, its ability to command fancy prices at the fag end of the season and also its frequent production of a fair-sized off-season crop of high marketing value marks out

this variety as the most suitable for commercial planting in this tract, even though its quality is inferior to that of Mulgoa and Andrews. Between Bangalora and Neelum, the latter commends itself more to the growers, because of its better fruit quality and its frequent habit of production of off-season crops.

With a view to gather some information about the possible effect of a heavy or poor crop in one season on the yield in the following seasons, the estimated yield records were further analysed separately for each variety. These revealed that, in the case of Neelum, for every 100 trees that bore heavy crops of fruits in 1936, only eight trees bore heavy yields in 1937, ten trees in 1938 and 13 trees in 1939. This shows that the possible exhaustion effect caused during 1936, had not been made up during the following three years. It further shows that, the popular conception of an off-year following alternately an on-year is not substantiated. Similarly, when the performance of the poor-bearing Neelum trees are traced, it is found that, of the 100 such trees in 1936, 78 in 1937, 87 in 1938 and 81 in 1939 continued to bear poor crops. In the same manner, out of 100 trees that bore heavy crops in 1936 in Bangalora, only ten in 1937 and 1938 and six in 1939 bore heavy crops, while of the 100 trees that bore poor crops in this variety in 1936, 62 in 1937, 94 in 1938 and 88 in 1939 continued to bear poor yields. All these facts seem to conclusively support the previously recorded inference that, in a given tree an on-year does not necessarily follow an off-year. In other words, the bearing in mangoes seems to be governed not entirely by the performance of the trees in the previous year nor by the supposedly existing phenomenon of biennial bearing, but mainly by the inherent character of the individual tree, including possibly parts thereof, and also by other environmental factors including the incidence of pests and diseases and cultural practices.

Orange performance records. It has been stated previously that sathgudi orange bears two main crops in a year in Ceded districts, but it often happens that irregular blooming periods also get intercalated between these two main periods, resulting in the availability of fruits practically throughout the year. The blooming period for the winter crop, which forms the largest bulk of the produce varies slightly from season to season, having occurred during the last three weeks of February in 1937 and 1938 and last week of January in 1939. The harvest of this chief crop of the year was done during December-January in 1936-37, November-March in 1937-38 and November-January in 1938-39. For the second crop, flowering has occurred from last week of September to the beginning of December, and harvest was done from June to August during the period under study. Prevailing prices in the market offer an inducement to the growers to pick immature fruits, while in some years premature harvest is necessitated by the attack of fruit moth, *Ophideres*. These factors are also expected to affect the tree yield not only during the season but also in the immediately succeeding one.

Unlike in the case of studies in mango orchards, it has been possible to take an actual count of the fruits borne on each individual tree in the two sathgudi plantations. Besides furnishing a more accurate standard for the grouping of the trees into heavy and low bearers, the above method has also shown an indication of the relation between the tree yields in the two bearing seasons. In the following statements are presented the information gathered from these two orchards during the first two years viz., 1936-37 and 1937-38 as also a summary of the compiled information collected during the entire 3-year period.

Statement No. 5. Summary of information gathered from Orange Orchard analysis.

Particulars	Garden No. 1		Garden No. 2	
	1936—37	1937—38	1936—37	1937—38
1. Percentage of non-bearing trees and trees bearing less than 50 fruits each.	23·6	7·2	52·9	25·2
2. Average number of fruits per tree for the year.	135·8	557·43	66·10	300·7
3. Average number of fruits per bearing tree in 1st season.	156·3	529·0	90·9	297·0
4. Average number of fruits per bearing tree in 2nd season.	28·5	20·8	35·7	6·5
5. Average number of fruits per bearing tree for the whole year.	154·8	565·63	84·4	329·8
6. Maximum yield per tree in 1st season.	935	1400	320	1200
7. Maximum yield per tree in 2nd season.	150	95	200	40

Statement No. 6. Showing the orchard efficiency analysis during 1936—39.

Season of bearing	Garden No. 1		Garden No. 2	
	Heavy bearers %	Low or No bearers %	Heavy bearers %	Low or No bearers %
1st season	17·48	12·62	19·80	30·21
2nd season	16·50	59·71	37·50	39·50

The above data make it clear that, from the point of view of gross crop yield, garden No. 1 has proved to be a distinctly more valuable asset than garden No. 2. This difference is primarily due to the existence of a larger percentage of non-bearing or low-producing trees in the first season and also due to a relatively lower tree yield in that season in the latter garden than in the former. Although garden No. 2 has shown during the 3 year period to possess a higher proportion of high yielding individuals, especially

of the class that bears the second season crop, this advantage has been offset by the other unfavourable features mentioned above.

While the size of crop per tree or garden or season is clearly subject to considerable variation the ratio between the yields of the two seasons continues to be very wide, so that the second crop forms but a very small part of the gross yield in the year. This, however, does not detract the economic value of the second crop, which usually sells at a rate thrice or four times of that realised for the fruits of the first crop.

It seems clear from the orchard effeciency data for the three-year period that, unlike in mangoes the consistently poor or low-yielding trees in sathgudi orange plantation form a small proportion, not exceeding 30·21% in the first season and 59·71% in the second season. Garden No. 1, which is reputed to be one of the most profitable in this tract possesses only 12·62% of the trees that are consistently unprofitable on the basis of the yield records of the first season. The analysed figures of cropping furnished for three typical sweet orange plantations by Hodgson (3) have shown that the percentage of unprofitable trees range from 13 to 32, while in the average orchard the percentage may be over 50. Judged by this standard, it seems that the best seedling orange groves of the Ceded districts can favourably compare with the best budded orange plantations in California. On the other hand, the percentage of profitable or heavy-yielding trees in California has been found by Hodgson to vary from 26 to 68, while in Philippines, the percentage of such trees has been found to range between 2·94 to 51·28 in the four Batangas mandarin groves (4). Notwithstanding the possible differences in the grouping of trees according to yields as adopted in California and Philippines, an inference that seems valid is that, there is scope in this tract for increasing the orchard yields by increasing the number of inherently high yielding trees.

Webber (5) and Batchelor and his co-workers (1) have shown that the variations in orange tree yield is likely to be considerably influenced by the variations inherent in the buds due to heritage. Even if it be true that, orchard environment may be more potent than genetic factors in influencing productivity (4), the value of selecting only such trees as have been raised from high-yielding individuals seems well established for ensuring maximum productivity. Since seed propagation in citrus, despite its polyembryonic character cannot be depended upon to produce every progeny true to the parents, such selection of budlings from high-yielding parents is only possible through vegetative propagation, especially through budding, which is the most economic of the latter methods.

Vegetative propagation is known to be specially valuable in mangoes, because of the mono-embryonic character of most of the Indian varieties. The continued and extensive recourse to this method through ages has however, not increased the proportion of inherently productive individual trees, possibly because of the lack of any selective process in the parent

material. Because of the alleged phenomenon of 'periodicity of bearing' in mangoes, it may also be impracticable to secure as high a proportion of consistently productive parent trees in a mango grove as in citrus.

Nevertheless, from the economic view-point of the grower, the most important measure that requires to be devised appears to be that, which has as its objective a definite increase in the orchard effeciency. Rigorous selection of parent material, control of the so-called phenomenon of 'periodicity of bearing', or employing suitable rootstocks are some of the possible methods that can be adopted towards the realisation of these objectives. On the other hand, in the case of sathgudi orange, while the value of selection of parents cannot be denied, the greater importance of cultural propagation and rootstock investigations appears to be indicated to enhance the orchard receipts through better fruit quality, disease resistance and an increased productivity in the medium or low-cropping individuals.

It also appears that the simple method of orchard analysis adopted in these investigations will be most useful in evaluating the intrinsic orchard value. It would thus furnish a more efficient means to the purchaser of a bearing orchard of determining the orchard value than any of the prevailing methods.

Summary. 1. An amazingly high percentage of unprofitable trees has been found to form a common feature in Neelum, Bangalora, Andrews and Mulgoa varieties of mango in the Ceded districts.

2. Out of 1143 trees of four varieties under study, there is only a single tree of Bangalora variety, which has consistently borne heavy crop of flowers during the four-year period. Not a single tree in any of the four varieties has produced heavy or medium crop of fruits consistently during this period.

3. Since over 95 % of the trees of Mulgoa and Andrew have borne consistently poor or no crop during the 3 out of four years under study, and since the percentage of heavy fruiting trees in any one year has not exceeded 2·6, it appears futile to include these varieties in commercial plantations.

4. Neelum has proved to be the most economically profitable variety in this region.

5. The popular conception that an off-year is invariably followed by an on-year or *vice versa* is not substantiated.

6. The orange garden No. 1 has proved to be a distinctly more valuable set than No. 2.

7. While the possibility of increasing the number of heavy-yielding trees by vegetative propagation and selection of parent material is indicated, increasing of yields of medium and low croppers are found to be of greater importance in oranges, unlike in mango orchards.

8. The simple method of orchard analysis adopted in these investigations is likely to offer an efficient means to the purchaser of a bearing plantation of determining the intrinsic value of the trees grown therein.

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