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The Value of an Estimate of Fruiting Potential in the Sultana

by

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One of the big problems facing grape producers in Australia as in other parts of the world is the large variation in yield from year to year. In most grape varieties fluctuations in yield are caused mainly by the effect of weather, pests, and diseases on the realisation of the crop potential, which is based on the number of bunch primordia and their development up to onset of bud dormancy. In the sultana, however, yield is also severely influenced by the number of fruitful buds formed and, in the Murray Valley Irrigation areas, too few bunch primordia are initiated in some seasons to ensure a full crop.

The fruiting habit of the sultana and the problems arising from it have for many years been studied at the Commonwealth Research Station, Merbein. One of the aspects which received early attention was the possibility of deriving a system of crop management which would reduce the annual fluctuations in yield. For this purpose it seemed necessary to obtain an early estimate of the seasonal fruiting potential, preferably prior to pruning.

BARNARD and THOMAS (1938) established that the percentage of fruitful shoots was an important and sometimes decisive factor in yield. They later suggested (THOMAS and BARNARD, 1938) that some degree of crop regulation could be achieved by adjusting pruning annually to a level which would allow the vines to fulfil their carrying capacity. ANTCLIFF and WEBSTER (1955 a) continued this work and developed a system whereby fruiting potential could be predicted each year prior to pruning from the fruitfulness of a sample of buds examined microscopically. They concluded that a reliable forecast could be obtained from an examination of 20 canes from each of ten district vineyards, and that the severity of pruning could profitably be adjusted to the fruitfulness found by this bud examination (ANTCLIFF, WEBSTER, and MAY, 1956).

For a number of years now the fruiting potential of the sultanas growing in the Sunraysia district — the irrigation areas of Mildura, Merbein, Red Cliffs, and Coomealla — has been estimated as an advisory service to growers and the results have been published in the local press each autumn before commencement of pruning.

This estimate applies only for vines which are not suspected of having suffered a reduction in bud fertility due to the effects of weather hazards or diseases. Such mishaps seldom affect the whole of the sultana growing area in the Murray Valley but individual vineyards are severely damaged at times. The effect on fruit bud formation depends largely on the stage of seasonal development reached by the vines at the time of the mishap (ANTCLIFF, WEBSTER, and MAY, 1957) and without examination of the buds it is often difficult or impossible to estimate the extent of the damage to next season's crop.

In this paper the usefulness of the district bud examination is critically examined, improvements to the system are described, and examples are given of how estimating bud fertility of damaged vines can assist in their management.

Results

Estimates of Crop Potential 1952 — 53 to 1959 — 60.

Each autumn from 1952 to 1959 a sample of sultana buds from the Sunraysia district was examined microscopically for fruitfulness. As briefly described by Antcliff and Webster (loc. cit.) the sample comprised the mature buds to bud 14 on 20 canes from each of 10 district vineyards, three in the Mildura and Merbein settlements and four in Red Cliffs. Within each settlement, represented roughly in proportion to its acreage planted to sultanas, the sites were selected at random on each of the major soil types. On each vineyard the 20 vines sampled were situated in a randomly selected area of approximately $^1/_3$ acre, one cane only being taken from each vine. Fruitfulness was determined by dissecting the freshly sampled buds under 20 × magnification without cutting sections. Where a bunch primordium was found an estimate of its size was obtained by measuring its length and greatest width.

In Table 1 the results of the examinations are shown together with the estimate of potential yield in cwt per acre calculated from Antcliff and Webster's regression (loc. cit., Fig. 14) and the actual harvested yield. The figures

Table 1

Per cent. fruitful buds, predicted, and actual yield (in cwt per acre), together with reasons for discrepancies between predicted and actual yield 1952 — 53 to 1959 — 60

Year	% Fruitful buds	Predicted yield cwt/acre	Actual yield cwt/acre	Difference due to
1952-53	70.0	37.9	35.4	Downy Mildew
1953-54	45.1	32.0	32.2	—
1954-55	61.5	36.2	32.4	Hail, rain at harvest
1955-56	52.2	33.9	20.9	Frost, rain at harvest
1956-57	43.3	31.5	33.8	Less severe pruning
1957-58	58.9	35.6	35.5	—
1958-59	70.1	37.9	30.8	Hail, anthracnose, heat
1959-60	58.2	35.4	26.1	Heat, bad setting

show that final yield and estimated potential yield agreed in only two of the eight seasons. The reasons for the discrepancies are also shown in the Table.

In five seasons harvested yield was lower than estimated yield due to adverse weather conditions. In each case estimates of the losses made by outside bodies, such as the Department of Agriculture of Victoria and the Victorian Dried Fruits Board, accounted largely for the discrepancies. The downy mildew outbreak in 1952-53 was one of the rare occasions when this disease reached economic proportions in the Murray Valley. It caused severe damage to individual properties and thus reduced the overall district yield. The losses due to hail in 1954-55 were estimated as about 2300 tons of dried fruit, reducing the overall district average by about two cwt per acre, the main damage again being restricted to individual properties. During the harvest period of February and March 2.06 inches of rain fell compared with a long term average of 1.60 inches, causing overall losses due to deterioration of fruit. In 1955-56 frost damage, again restricted to individual properties, was estimated as about one cwt per acre over the whole district: but the losses during harvest, caused by 3.40 inches of rain, were far more serious. It was estimated that one third of the crop was lost due to fruit becoming mouldy either on the vines or during drying. Of the losses in 1958-59 2.5 cwt per acre were due to hail, again of localised occurrence; anthracnose, a heat wave during January, and also the recommendation to prune more severely following the high fruitfulness found in autumn, accounted for the rest. The heat wave in November 1959, which interfered with setting, was extremely severe; from November 20th. to 28th. the mean daily maximum reading was 99.1° F, the mean daily maximum for the month being 87.7° F compared with a long term average of 83.2° F.

In one season, 1956-57, final yield was higher than estimated yield and this was probably due to the estimate of fruitfulness being accepted as a guide to pruning. The potential fruitfulness found in that year was lower than the long term average of about 50 %, and growers were therefore advised to prune lightly. If the advice was generally accepted final yields should have been higher than anticipated. On the 200 test vines an average of 137.3 buds were left by the growers compared with an average of 116.3 buds in the other seven years. A similar increase in number of buds retained at pruning throughout the district would account for the higher yield harvested.

Estimating Fruitfulness by Examining Bud Positions 4, 9, and 14 only

The results presented in the previous section show the value of the estimate of fruitfulness in seasons such as 1956-57, but they also indicate its limitations. The method used required the annual testing of approximately 2800 buds, and the sampling, preparing, and examining of so large a number of buds took up a considerable amount of time. Once it was established that the forecasting service was likely to become permanent, investigations were started to simplify the procedure and reduce the amount of work needed.

Antcliff and Webster (loc. cit.) showed by statistically analysing their results for the seasons 1946 to 1948 and for 1952 to 1954 that per cent. fruitful buds did not interact between seasons and bud positions. A similar analysis of the data for the years 1952 to 1959, described in the previous section, substantiated their findings, the interaction between seasons and bud positions being just significant at the 5 % level compared with very large, very highly significant effects for the individual factors. The data were therefore examined in more detail to test whether per cent. fruitful buds of a selection of bud positions would give similar results to that of all bud positions to bud 14.

From all the possible combinations of bud positions tried, 4, 9, and 14 were found to represent the general trend of the curve of per cent. fruitful buds per bud position best. In Table 2 per cent. fruitful buds for the years 1945 to 1959

Table 2

Per cent. fruitful buds for bud positions 1 to 14 and for bud positions 4, 9, and 14 for examinations 1945 to 1959

Year	Bud positions 1 to 14	Bud positions 4, 9, and 14	Difference
1945	63.1	67.5	+ 4.4
1946	52.0	53.2	+ 1.2
1947	43.7	42.9	− 0.8
1948	32.0	33.3	+ 1.3
1949	64.2	66.2	+ 2.0
1950	33.8	34.9	+ 1.1
1951	46.2	48.3	+ 2.1
1952	70.0	69.8	− 0.2
1953	45.1	47.5	+ 2.4
1954	61.5	62.3	+ 0.8
1955	52.2	55.6	+ 3.4
1956	43.3	40.4	− 2.9
1957	58.9	59.7	+ 0.8
1958	70.1	73.7	+ 3.6
1959	58.2	58.6	+ 0.4

for all bud positions from 1 to 14 is compared with per cent. fruitful buds calculated by extracting buds 4, 9, and 14 from these data. Also shown are the deviations of the latter from the former. Statistical analysis of the data showed that the means of the two systems differed significantly at the 5 % level, that for the three-bud system being 1.3 % higher. Differences of up to ± 5 % can be regarded as permissible for practical purposes, and from these data such a difference can be expected by chance only once every 41 years.

Thus it appeared that sampling of buds 4, 9, and 14 could replace sampling of all buds to 14. However a further test on two completely independent samples was needed and this was done in 1959. A similar number of buds as in the 200-cane sample was collected by taking ten buds from each of the three positions on each vineyard, one bud only from each vine sampled. Thus a very much greater number of sites was sampled, 102 in all: they were selected by covering the whole of the sultana growing area of Sunraysia with a grid, each square representing approximately 270 acres, and picking one vineyard per square at random. The results of the two examinations agreed very well, the fruitfulness of the whole-cane sample being 58.2 % and that of the three-bud sample 59.0 %. Statistical analysis after angular transformation of per cent. fruitful buds showed 95 % confidence limits of $\pm$ 2. 3 % for the three-bud sampling. Twenty-one vineyards would have been sufficient to give a 95 % confidence limit of $\pm$ 5 %, and this would involve the sampling of approximately 600 buds.

The large number of sites sampled in 1959 allowed a much more accurate test of differences in fruitfulness between the settlements within Sunraysia than that described by ANTCLIFF and WEBSTER (loc. cit.). Table 3 shows the num-

Table 3

Per cent. fruitful buds in the three settlements of Sunraysia 1959 and 1960

Settlement	1959		1960	
	No. Sites	% Fruitful buds	No. Sites	% Fruitful buds
Mildura	35	59.5	9	60.4
Red Cliffs	33	56.2	8	61.7
Merbein	21	62.5	5	56.0

ber of sites tested in the three major settlements of Sunraysia for 1959, and the mean per cent. fruitful buds found. Data for 1960 are also included. The results justified the conclusions reached by the authors mentioned above that per cent. fruitful buds does not differ between the settlements in the Sunraysia district.

The area where sultanas are grown along the Murray extends over an aerial distance of almost 250 miles. ANTCLIFF and WEBSTER (loc. cit.) using rather small samples, found no evidence for variation in fruitfulness between the

Table 4

Per cent. fruitful buds in the four sultana growing districts along the Murray River 1958 to 1960

District	1958		1959		1960	
	No. Sites	% FB*)	No. Sites	% FB	No. Sites	% FB
Sunraysia	10	74	102	59	25	58
Robinvale	7	71	13	56	12	54
Mid Murray	16	82	21	63	21	56
South Australia . .	10	82	29	61	28	59

*) FB: Fruitful Buds

major districts — South Australia, Sunraysia, and mid Murray (for locality map see the above mentioned paper). A further area, Robinvale, has since come into full production and with the new method of sampling, and the simpler method of examination to be described in the next section, it has become possible to survey the areas outside Sunraysia in more detail. The results are shown in Table 4. With the exception of 1958, when South Australia and mid Murray were significantly more fruitful, per cent. fruitful buds was similar and did not differ statistically between the districts in any of the three seasons. The 1958 result was verified by counting the number of bunches on the vines after bud burst. The higher fruitfulness in the two districts in this one season cannot be explained.

The Present System of District Bud Examination

Results presented in the preceding section show that examining samples of approximately 600 to 800 buds taken from 20 to 25 vineyards will give an estimate of sultana fruitfulness very similar to and well within the stipulated limits of error of a sample of approximately 2800 buds from ten sites. The annual routine examination has therefore been changed as from 1960 to sampling ten buds each from bud positions 4, 9, and 14 on 25 sites.

Up to 1959 bunch primordium size has also been measured in the hope of improving the forecast by taking into account bunch development up to dormancy. Antcliff and Webster (loc. cit.) had shown that per cent. fruitful buds and bunch primordium size were positively correlated but no information was available on the relation between primordium size and final bunch size. The 20 vines on each of the ten sites from which the canes were sampled were also harvested every year. For the years 1952-53 to 1958-59 mean bunch primordium size and mean bunch weight per site were statistically analysed. Due to harvest losses on some sites in some years only 58 of a total of 70 possible pairs of data were available and this necessitated the use of a non-orthogonal, double-classification analysis of covariance. It was found that the two variates are not correlated, the regression coefficient being 0.00745 ± 0.01155. There is no doubt that final bunch size is predisposed by bunch primordium size (Barnard and Thomas, 1933). However the development of the bunches from bud burst to harvest is so strongly influenced by environmental conditions that for the purpose here discussed bunch primordium size appears to be unsuitable as a measure of yield potential.

The practice of measuring bunch primordia was therefore discontinued in the new system. This made it possible to change the method of microscopical examination. Instead of dissecting buds carefully in order to keep the bunch primordia fully intact the top of the bud is now cut parallel to the base of the bud until shoot apex and bunch primordium, if present, appear in horizontal section. These cuts are freehand sections of the fresh material made under low magnification without any previous preparation.

For the sampling of the buds a pair of anvil-type secateurs has been modified to allow the quick removal of the bud without severing the rest of the cane (Fig. 1).

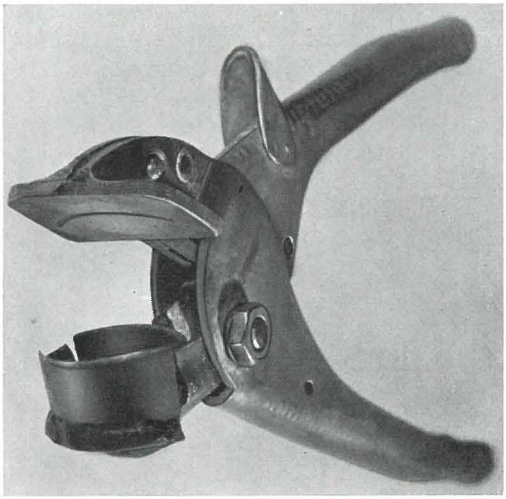

Fig. 1: Modified pair of anvil-type secateurs for the removal of single buds

Estimating Fruitfulness by Forcing Growth

The methods of estimating sultana fruitfulness described so far have the disadvantage of requiring a microscope and considerable technical skill. Briza and Milosavljević (1954) and Wurgler, Leyvraz, and Bolay (1955) described methods where by forcing buds during the later part of winter rest fruitfulness can be determined by simply counting the number of inflorescences on the young shoots. For this method to be useful for the purpose discussed here the results have to be obtained before pruning is commenced in early June. Antcliff and May (1961) described the course of dormancy in the sultana under Australian conditions and found that buds on single-bud cuttings collected during March and treated with ethylene chlorhydrin will burst quickly enough to allow such a count to be made.

A full-scale comparison of forced growth and microscopical examination for determining per cent. fruitful buds was made in 1958. From March 11th. to 13th., 200 canes were collected from the same vines used for sampling for the microscopical examination, treated with ethylene chlorhydrin, separated into single bud cuttings from node 3 to node 20, and grown at 20° C. The date on which each bud burst was noted and those buds which had not burst after four months were examined microscopically. As the examination was also designed to measure inflorescence weight the buds were dissected under low magnification on the day when the first green leaf tips became visible through the bud scales instead of being left to grow until the inflorescences could be observed by naked eye. The results of this examination compared with those from the microscopical examination described earlier are shown in Figure 2.

It will be seen that over half of the buds in the first sample had burst after two months and this appeared to be ample for determining fruitfulness. The fruitfulness of even the first 10 per cent. of the buds to burst agreed quite closely with that found at the microscopical examination of the second sample. The proportion of fruitful buds tended to become greater the later the buds

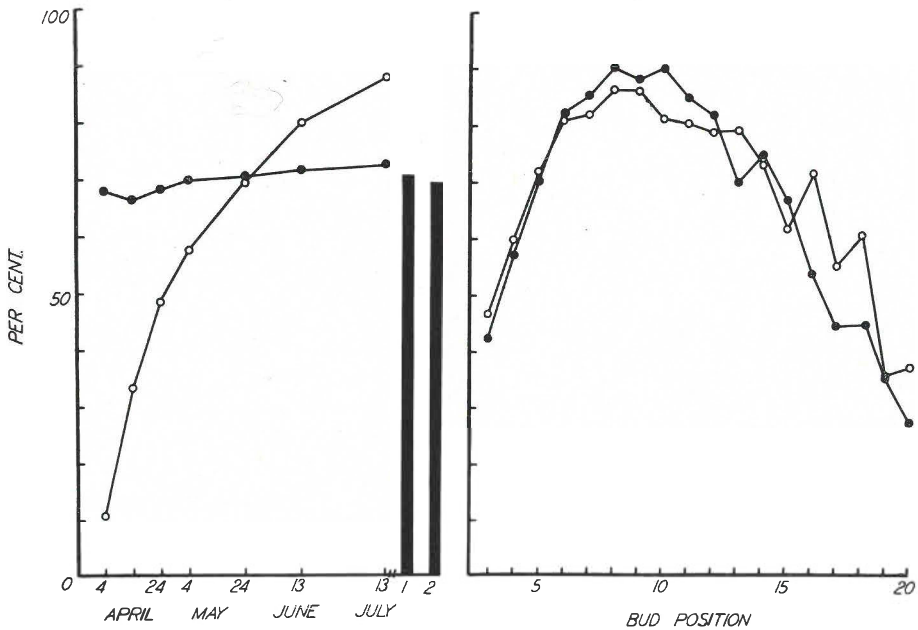

Fig. 2: Left. Per cent. bud burst (○—○) and per cent. fruitful shoots (●—●) in a sample of single bud cuttings at intervals after sampling. The histogram shows the overall per cent. fruitful buds in this sample, including those which did not burst, (1) and in a comparable sample examined microscopically (2)

Right. Per cent. fruitful buds at each bud position for sample 1 (○—○) and sample 2 (●—●)

burst but this increase was too small to affect the accumulated totals to any extent. This tendency is in direct contrast to that found at bud burst in the field (Antcliff and Webster, 1955 b), where there is a pronounced drop in fruitfulness the later buds burst. The figures for per cent. fruitful buds at each bud position show very good agreement between the samples.

Thus the method of determining fruitfulness by forcing buds to grow is quite practical and could, in fact, be used by advisory officers or individual growers. It would not be necessary to grow the buds under very closely controlled temperature, and testing of buds 4, 9, and 14 only would be sufficient, thus reducing the number of buds tested similarly to the microscopical examination. Furthermore, if buds are collected before the beginning of deep organic dormancy (Antcliff and May, 1961) treatment with ethylene chlorhydrin or any other dormancy-breaking agent would not be necessary.

At Merbein, fruitfulness is still estimated by examining buds microscopically because this method appears to be more convenient if an operator with the necessary skill and a microscope is available.

Examining the Fruitfulness of Damaged Sultana Vines

Whenever vines are affected by damaging influences such as frost, hail, waterlogging, drought, diseases, etc. losses are not restricted to the current season's crop but bunch initiation and development inside the bud are also affected. Antcliff, Webster, and May (1957) have shown that in such cases losses of the current season's crop can not be reduced but that some measure of compensation can be achieved for the next season by appropriate modifications of winter pruning. As the extent of the damage is very variable and dependent on the time of occurrence in relation to the stage of bud development it is quite often impossible to give reliable advice on the pruning of damaged vines without examining their fruitfulness. In the following, some examples are presented when examining fruitfulness made such advice on pruning possible.

Frost: Antcliff, Webster, and May (1957) described two different occasions when frost damaged sultanas. In the first case the damage occurred very early in the season and fruitfulness was actually increased in the distal part of the canes, probably due to lack of competition from the current season's crop. In the second case the frost hit shortly before bunch initiation was due to commence, and here fruitfulness was reduced on the basal part and increased on the distal part of the canes. The finding of Antcliff, Webster, and May (1955) that the length of the cane is not important in pruning, as long as the total number of buds per vine is maintained, obviously does not apply in such cases. Here examining all buds to at least bud 20 allows pruning recommendations to be made which will take best advantage of the altered distribution of fruitful buds along the cane.

Hail: Hail damage to next season's fruitbearing potential is caused by a combination of factors, namely actual killing of primary buds, mechanical damage to the shoots carrying the buds, and removal of correlative inhibition by severely tipping shoots which results in the premature burst of primary buds and in excessive development of lateral growth. All the effects are entirely detrimental with the exception of the last mentioned which can in some cases be used to achieve some form of crop compensation. In Table 5 the results of two examinations are compared, the first following a hail storm on November 7, 1954 and the second after a similar storm on November 19, 1958. The figures show that fruitfulness in each case was serverely reduced on the main canes, mainly due to the death of primary buds. Growers were in each case advised to retain as much pruning wood as possible, in particular supplementing damaged canes by matured lateral growth. In 1958-59 field observations confirmed that better crops were obtained on vineyards where this advice had been followed.

Flooding: During winter and spring 1956 very high flood waters of the River Murray inundated parts of the Renmark area, and a number of lowlying vineyards in other districts. Some vines were completely under water until the end of November, almost three months after bud burst should have commenced. Very little, if any crop was produced by the flooded vines during that season, and there was grave anxiety whether fruit buds had developed. Examination of a number of canes from vineyards flooded to varying height

Table 5

Percentage of dead buds and of fruitful buds on canes and on lateral continuations after hail damage in 1954 and 1958

	1954			1958		
	% Buds dead	% Fruitful buds all	% Fruitful buds live	% Buds dead	% Fruitful buds live	% Fruitful buds dead
Canes proper . .	16.6	34.6	42.0	37.5	19.8	31.7
Lateral continuation	0.03	53.9	55.7	—	36.8	37.6

and for varying lengths of time showed that all surviving vines had produced a reasonable number of fruits buds, approximately 15 % less than the district average.

Downy Mildew: Following the severe outbreak of downy mildew in November 1953, the fruitfulness of sultanas was determined on a property where all the current season's crop had been lost and where on part of the vineyard the vines had also been defoliated. The fruitfulness of the buds on twenty canes each sampled from the disbunched vines and the disbunched and defoliated vines was 50.4 % and 47.7 % respectively, compared with a district fruitfulness of 45.1 %. Against all expectation bud fertility had not been reduced by the disease.

Discussion

Estimating vine fruitfulness by examining dormant buds has proved a most valuable guide in sultana growing. However it does not give reliable final crop estimates, particularly for marketing purposes. This has been recognised by Alleweldt (1958) who compared the fruitfulness of dormant buds of a number of grape varieties by preparing stained sections. He found that differences in fruitfulness could be detected between vines of different age, pruned in different ways, and grown on different stocks, and concluded that the method was useful in determining the effect on fruitfulness of climatic factors, ecological differences, and cultural practices. But he regarded it as unsuitable for forecasting yield as had been suggested by Wurgler, Leyvraz, and Bolay (1955) who examined buds by forced bursting and estimated yield from the number of inflorescences in each of three size-groups at a defined stage of development after bud burst.

The method developed for sultanas growing in the Murray Valley is primarily designed to help growers overcome or at least reduce the very great fluctuations in yield from year to year. By advising them prior to pruning of the potential fruitfulness they are able to adjust the level of pruning to the yield potential. But as final yield is to some considerable extent influenced by conditions subsequent to pruning, such adjustments have to be made within fairly wide limits. The greatest benefit is derived in years of abnormally low fruitfulness. By retaining greater number of canes at pruning, some degree of yield compensation will be achieved in such seasons.

The successful use of the method under Australian conditions is made possible by several favourable conditions. Firstly, the fruitfulness of the sultana varies considerably from year to year and this variation expresses itself in the final yield. Secondly, fruitfulness is fairly uniform throughout the areas along the Murray in any one year. This is undoubtedly due to the reasonably uniform climate of the region, at least during the period of bunch initiation. For the formation of fruitful buds climatic effects are more decisive than soil type or cultural practices, although these are very important for the realisation of the potential crop. This is borne out by the fact that in the analysis of per cent. fruitful buds for the years 1952 to 1959 mentioned earlier differences between seasons were very much greater than differences between vineyards and that the interaction between vineyards and seasons was quite small. All these factors help to make the fruitfulness of a sample of less than 1000 buds representative for the fruitfulness of approximately 45,000 acres of sultanas.

The estimate of fruitfulness by itself can not be used to predict final yield with any degree of accuracy although in some seasons the two data do agree well. However it can serve as an accurate basis for adjusting estimates of the developing crop throughout the season. Sanderson (1954, p. 146-7) found that, in general, estimates of the condition of the grape crop from three months before harvest onward agree fairly well with final yield. He concludes that this is due to the "critical periods" (namely fruit set) preceding the harvest by about that period (approx. 3 months). For the sultana in the Murray Valley a second "critical period" exists twelve months earlier when bunch initiation takes place. The method of estimating fruitfulness discussed here could very well form the basis for an exact prediction of final yield, if combined with observations and measurements during the period from bud burst to harvest.

Summary

The potential yield of sultanas growing in the Sunraysia Irrigation Area of the Murray Valley, Australia, is estimated from the fruitfulness of a sample of approximately 750 buds. The result is, in most seasons, representative not only for Sunraysia, but also for all the sultana growing areas along the Murray.

The examination is carried out by collecting buds from bud positions 4, 9, and 14 from 25 vineyards and inspecting them microscopically by successive decapitation.

Microscopical examination of buds is compared with a method of forced growth which allows examination by naked eye.

Forecasting fruiting potential is mainly intended to give a reliable guide to severity of pruning, particularly by recognising years of abnormally low fruitfulness.

Examination of dormant buds from vineyards damaged by such mishaps as frost, hail, inundation, or disease is helpful in assessing the extent of the damage to fruitfulness.

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