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The Importance of Harvest Date and Plant Density on the Yield and Quality of Tasmanian Peppermint Oil[1]

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Additional index words. essential oil, *Mentha piperita*

Abstract. **Oil yield of peppermint (*Mentha piperita* L.) per unit area obtained from plant density treatments 30 and 40 plants/m^2, reached a maximum early in the growing season, whereas oil yield from the lower density treatment, 10 plants/m^2, continued to increase even at a menthol content of 50%. The latter density treatment yielded less oil per unit area. At the 2 highest densities, herb harvested at a stage when oil contained 45% free menthol resulted in maximum oil yield and optimum oil quality. Delaying harvest once the above stage had been reached resulted in increased levels of menthol but at the expense of increased levels of menthofuran and decreased oil yields. As the growing season progressed, menthol and menthyl acetate contents of oil increased while menthone decreased. This effect was accelerated at the high plant densities.**

Timing of harvest is of critical importance for both yield and quality of oil extracted from *Mentha piperita* (6). A desirable time to harvest might coincide with maximum oil quality and oil yield per unit area but in practice these may be in conflict.

Numerous workers have found that for optimum oil and menthol contents, plants should be harvested at the full bloom stage (1, 3, 9, 10). Ellis and Gaylord (2) considered such a method unreliable and too dependent on environmental conditions. They found that the oil content of plants increased to a stage at which the oil contained 45% free menthol. If plants continued growing, the yield of oil per plant decreased. This decrease was accompanied by an initial increase in free menthol followed by a decrease in free menthol. Within 10 to 15 days the decrease in oil yield amounted to 30% of the total oil yield. An increase of similar magnitude was found to occur in the period which preceded the time of optimum harvest.

Compositional changes in peppermint oil occur with maturity and these changes are important determinants of oil quality. Maturation of peppermint oil is associated with increased levels of menthol, isomenthol and menthyl acetate, and decreased levels of menthone and isomenthone (6, 7).

Few references appear in the literature on the effect of plant density on the yield or quality of peppermint oil. Guenther (4) considered it advisable to produce bushy plants, since most oil is produced in leaves. Reference is made to the difference in stage of maturity of row and meadow mint (4, 9). Commonly, meadow mint matures earlier than row mint.

Nelson *et al.* (8), found that oil yield was highest when the herb was allowed to grow in solid stands with no thinning or cultivation. Observations by Hamon and Zuck (5), indicated that meadow mint tended to become overcrowded resulting in loss of lower leaves, lowering the oil yield.

It is the normal cultural practice in Tasmania to plant new fields of mint in rows about 75cm apart. In the second and subsequent years an almost uniform stand of herb, commonly referred to as meadow mint is developed. As a consequence of this meadow mint habit, where plant densities of 50 to 70 plants/m^2 are common, competition for light becomes very severe towards the latter part of the growing season. This results in tall plants with leaves present only on the uppermost portion of the stem.

The following experimental work is concerned with the effect of cutting date and plant density on quality and yield of Tasmanian peppermint oil, grown under commercial conditions.

Materials and Methods

Experiment 1. This experiment consisted of a 4 x 4 factorial, arranged in 3 randomized complete blocks. Each block consisted of 16 plots which were 3 x 3m. The trial was located at

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Fenton Forest, Glenora, in the Derwent Valley area of Tasmania, in a commercial stand of 'Black Mitcham' peppermint.

The treatments were as follows:–

1) Planting density: 10 (D1), 20 (D2), 30 (D3), and 40 (D4) plants/m^2.
2) Harvest dates: January 3 (C1), 13 (C2) and 28 (C3), and February 7 (C4), 1977.

On the appropriate cutting date the central 4m^2 of each plot was harvested. The harvested herb was weighed and a subsample of 1.5kg taken for drying and distillation. All plots were handled in the same manner as the main commercial planting.

Experiment 2. In 1978, 2 experimental areas were established. The first of these areas was at Rotherwood, Ouse, in the Derwent Valley area of Tasmania (Site 1), and the second location was in the Huon Valley area of Tasmania at Castle Forbes Bay (Site 2). Plant densities at Site 1 and Site 2 were 30 to 60 plants/m^2 and 10 to 20 plants/m^2, respectively. Each trial consisted of 3 randomized complete blocks with 9 plots within each block. The plots were 1.5 × 1.4m. Samples were taken at weekly intervals throughout the growing season.

The statistical significance of all data reported in this paper is based on LSD (5%).

Gas chromatographic technique. Gas chromatographic analyses of oil samples was conducted using a Pye Unicam Series 104 Chromatograph, fitted with a 56M × 0.5mm I.D., F.F.A.P., SCOT Capillary Column. Operating conditions were as follows: carrier gas (N_2) flow rate 2ml/min, air pressure 0.90kg/cm^2 and hydrogen pressure 1.25kg/cm^2. The column oven temperature was programmed from 80 to 160°C at 2° per min. An injection volume of 0.1μl was sampled from 1ml of peppermint oil, 1ml of 20% β-methylnaphthaline, made up to 5ml with redistilled *n*-hexane. The identification of peaks eluting from the SCOT column was made by comparing the retention times of peaks to a sample chromatogram run on a similar column. In addition, authentic samples of menthone, menthofuran, menthol and menthyl acetate were added to a sample of oil to confirm the identity of these peaks.

Drying. Prior to distillation all peppermint samples were dried under greenhouse conditions for 1 to 2 days until they had reached a moisture content of approximately 30 %.

Distillation. All herb samples were comminuted and immediately distilled. The distillation apparatus consisted of a 20 liter aluminum pressure cooker. This pressure cooker was modified by blocking the pressure release outlet and fitting a glass condenser to the lid. The condenser retained the oil and returned the distillation water to the cooker. The interior of the pressure cooker was fitted with a stainless steel screen which was supported 10 cm above the surface of the boiling water. The capacity of the unit was about 800g of dried herb. In each distillation run, 1 liter of water was added to the unit and the distillation rate maintained at 6ml per minute. Complete exhaustion of the herb was found to require 1 to 1.5 hr depending on the quantity of herb and its moisture content.

Results

Experiment 1. Dry matter yield (Fig. 1) increased from C1 and C4 at all plant densities. As the growing season progressed the initial difference between D2 and D4 became less pronounced, resulting in no significant difference in yield obtained from the three highest density plantings. The lowest density planting yielded significantly less than all other plantings at the last 2 harvests. Oil yield (Fig. 2) increased from C1 to C2 in the 2 highest density treatments after which no significant change occurred. However, an increase in yield from C2 to C4 did occur in the 2 lowest density treatments. Over all harvests, the lowest plant density treatment resulted in significantly less oil than the higher plant density treatments.

With respect to oil composition, menthone (Fig. 3) increased initially then decreased with time at the lowest density treatment. The only other significant change in menthone with time was a decrease at plant density D2 from C2 to C4. At cutting dates C2 and C3 the menthone level in the lowest density treatment was higher than that found in the highest density treatment. Menthol (Fig. 4) increased from C1 to C4 at all plant densities. Planting density had no significant overall effect on menthol levels, however, at C3 the menthol level from D3 was higher than D1. Menthyl acetate (Fig. 5) increased from C1 to C4 at all plant densities. The only significant difference in menthyl acetate levels between plant densities was an increase from D1 to D4 at cutting dates C1 and C4. Menthofuran (Fig. 6) decreased from C1 to C3 at all plant densities. An increase in menthofuran occurred between C3 and C4 in the lowest density planting. Levels of menthofuran resulting from the highest density treatment at cutting dates C1 and C4 are significantly lower than at the lowest density treatment.

Experiment 2. Dry matter yield of herb (Fig. 7) increased with time at both sites. At site 1, a decrease occurred at the end of the experimental period. Dry matter yield was highest at site 1, except on the last harvest date. Oil yield (Fig. 8) increased initially at both sites. At site 1 oil yield did not change significantly from 9/1 to 20/2, after which a decrease occurred. Oil yield continued to increase throughout the growing season at site 2. Site 1 yielded more oil than site 2 from January 2 (2/1) to February 13 (13/2).

With respect to oil composition, menthone (Fig. 9) decreased from January 2 (2/1) to February 27 (27/2) at both sites. At the beginning of the experimental period the menthone levels at site 2 were higher than at site 1, but these differences became less pronounced as the growing season progressed, resulting in no significant difference in menthone levels between sites at the end of the experiment. Menthol (Fig. 10) increased from January 2 (2/1) to February 27 (27/2) at both sites. At all harvest dates where a significant difference in menthol levels existed between sites, oil from site 1 was highest in menthol. Menthyl acetate (Fig. 11) increased overall comparing site 2 to site 1, and increased significantly from the beginning to the end of the experimental period. Whereas harvest date had no significant effect on menthofuran (Fig. 12), levels at site 2, an increase in menthofuran occurred towards the end of the growing season at site 1. This increase in menthofuran at site 1 resulted in a significant difference between sites, with site 1 having higher menthofuran levels at the end of the experimental period.

Discussion

At site 2 a plant density of 10-20 plants/m^2 gave an oil yield similar to the corresponding plant density treatment of experiment 1. In both cases the low yield of oil per unit area could not be compensated for by increased production per plant within acceptable limits of oil quality. At high densities (30 to 40 plants/m^2) the yield of oil per unit area reached a maximum early in the growing season. However, at site 1 there was a significant decrease in oil yield at the last harvest. Thus harvesting should take place any time maximum oil yield is reached and before the final decrease in oil yield, provided the quality of oil is within acceptable limits.

Peppermint oil of high quality should contain at least 45% free menthol, have low levels of menthofuran and balanced amounts of the many other components (4). Provided that high plant densities (30 to 40 plants/m^2) are employed, a menthol content of 45% may be achieved during the period of maximum oil yield per unit area. In addition, the results indicate that if harvesting is delayed once the free menthol levels are considered satisfactory, the menthol levels do continue to increase, but at the expense of increased levels of menthofuron.

Under Tasmanian conditions, maximum oil yield and optimum oil quality was achieved by harvesting when the free menthol content of the oil had exceeded 45%. In these experiments, this occurred when plants formed a terminal inflorescence about 1 to 2 cm in length. Should plants reach the full bloom stage, as is the normal procedure in many major production areas, this would result in high levels of menthofuran and decreases in oil yield per unit area.

The observed changes in oil composition with time are in general agreement with previous reports (6, 7). Menthol and menthyl acetate increased and menthone decreased towards the end of the growing season. Menthofuran decreased or remained constant throughout most of the season and in both experiments a significant increase was found to occur at the end of the experiment. In experiment 1 this increase occurred in the lowest density treatment and in experiment 2 at site 1, which was considered to be a high density planting relative to site 1. Virmani and Datta (9) reported that the level of menthofuran is greatest in areas of the plant where metabolism is most active and, in particular, the inflorescence. In experiment 1, site 1 was observed to be at a more advanced stage of flowering than site 2 at the end of the experiment which may explain the higher levels of menthofuran.

Plants growing at a density of 40 plants/m^2 were observed to have a single stemmed form, with terminal inflorescences. In contrast, plants growing at a density of 10 plants/m^2 tended to produce many lateral shoots prior to inflorescence formation. Such lateral shoots would be expected to contain more immature oil which may explain the earlier stage of maturity found in oils obtained from such plants. This earlier stage of oil maturity in the lowest plant density treatment is reflected by higher menthone levels and lower menthyl acetate levels.

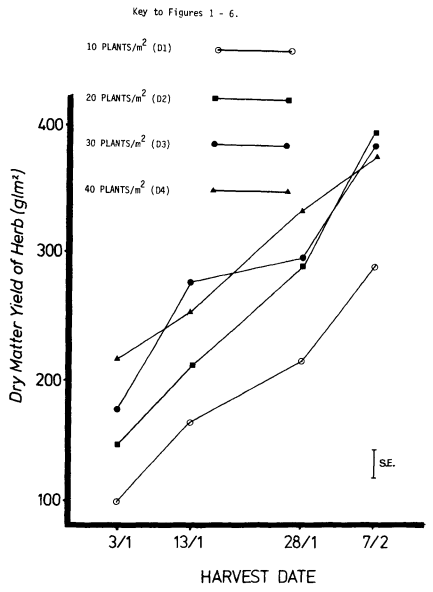

Fig. 1. Yield of herb in relation to density and date of harvest, experiment 1, 1977.

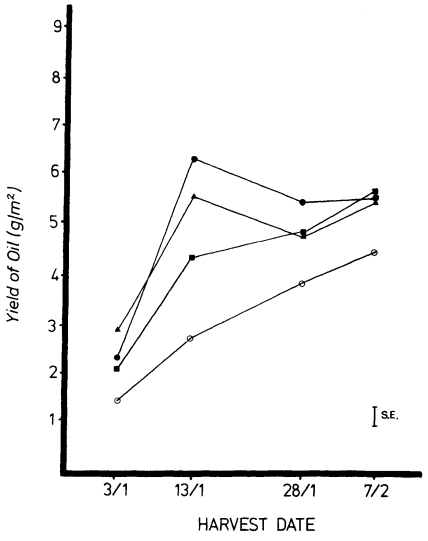

Fig. 2. Yield of oil in relation to density and date of harvest, experiment 1, 1977.

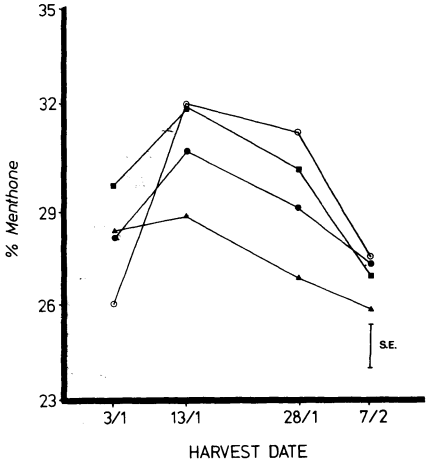

Fig. 3. Effect of harvest date and plant density of menthone composition of oil, experiment 1, 1977.

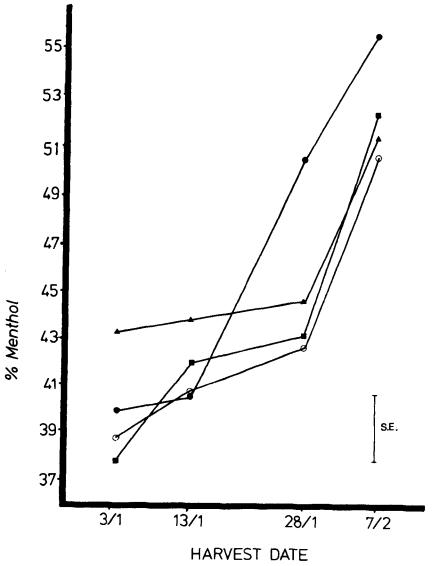

Fig. 4. Effect of harvest date and plant density on menthol composition of oil, experiment 1, 1977.

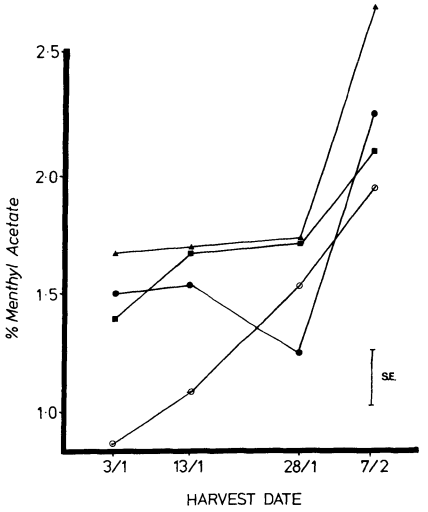

Fig. 5. Effect of harvest date and plant density on menthyl acetate composition of oil, experiment 1, 1977.

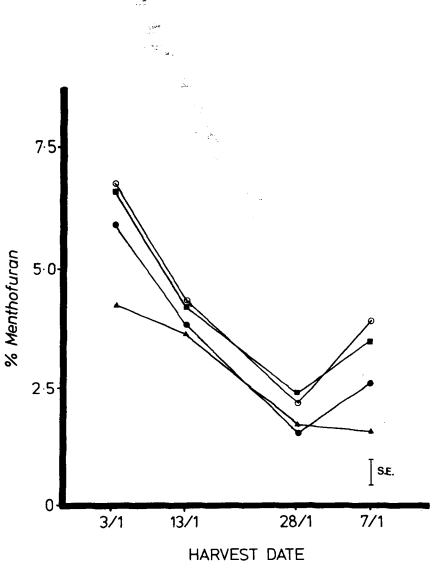

Fig. 6. Effect of harvest date and plant density on menthofuran composition of oil, experiment 1, 1977.

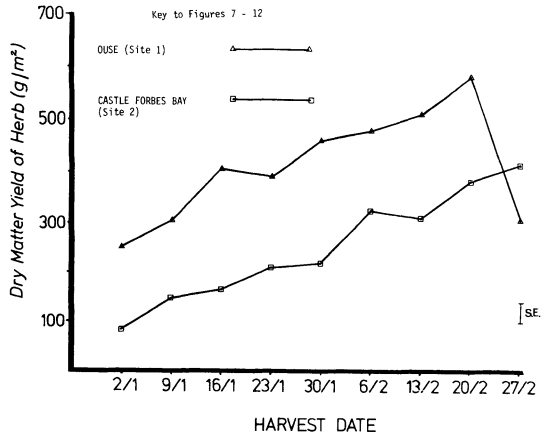

Fig. 7. Yield of herb in relation to date of harvest at Ouse and Castle Forbes Bay, experiment 2, 1978.

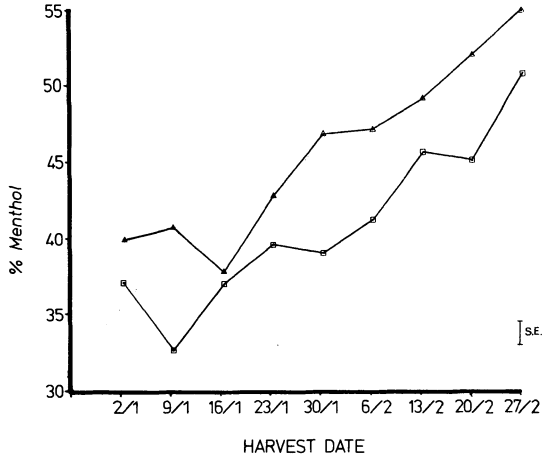

Fig. 8. Yield of oil in relation to date of harvest at Ouse and Castle Forbes Bay, experiment 2, 1978.

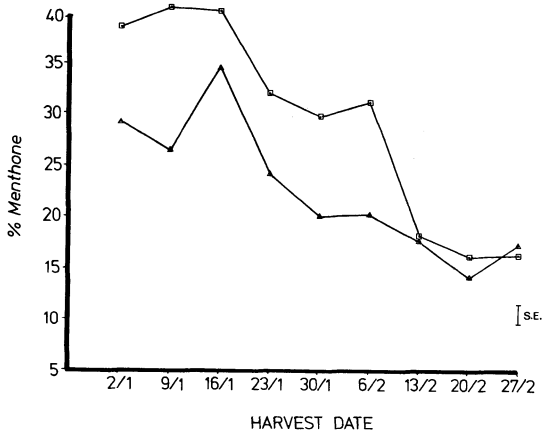

Fig. 9. Effect of harvest date on menthol composition of oil at Ouse and Castle Forbes Bay, experiment 2, 1978.

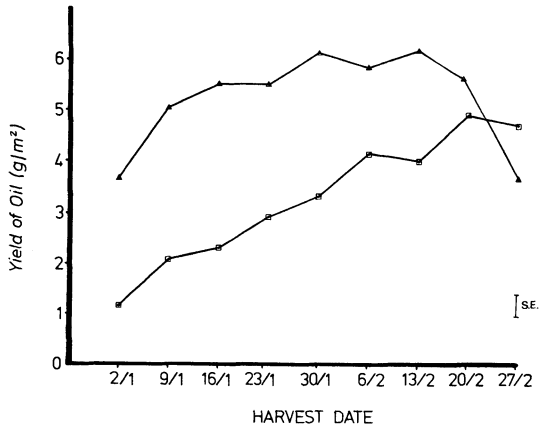

Fig. 10. Effect of harvest date on menthone composition of oil at Ouse and Castle Forbes Bay, experiment 2, 1978.

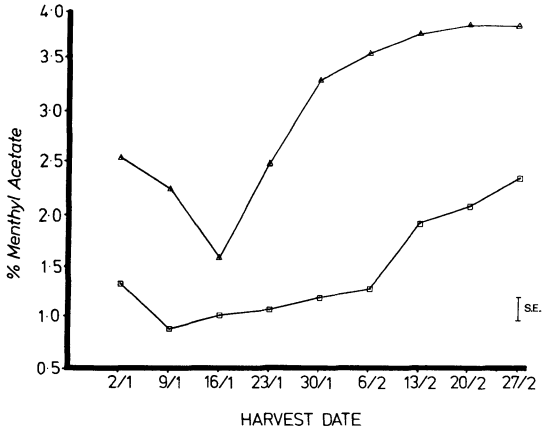

Fig. 11. Effect of harvest date on menthyl acetate composition of oil at Ouse and Castle Forbes Bay, experiment 2, 1978.

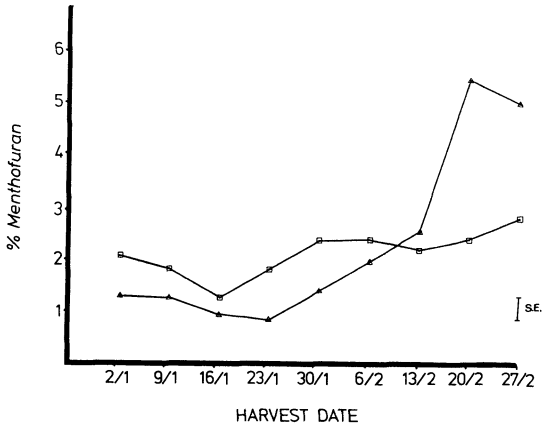

Fig. 12. Effect of harvest date on menthofuran composition of oil at Ouse and Castle Forbes Bay, experiment 2, 1978.

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Factors Associated with Surface Pitting of Sweet Cherry[1,2]

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Additional index words. soluble solids, firmness, gibberellic acid, hydrocooling, bruising, *Prunus avium*

Abstract. **Six annual surveys indicated that % soluble solids and fruit weight were the only consistent predictor variables for fruit surface pitting in 'Lambert' sweet cherry (*Prunus avium* L.). Both were inversely related to pitting. Similar associations were found 'Bing' when fruit were handled excessively. In spite of tree-to-tree variation, the degree of pitting was relatively uniform in a given orchard in a given year. High and low percentage pitting orchards appeared to be fairly consistent over the 6 years, but intermediate ones were extremely variable. Postharvest factors (time delay prior to storage, hydrocooling temperature, or storage temperature) had little or no effect on surface pitting. Foliar sprays of gibberellic acid (GA_3 or GA_{4+7}) applied 3 weeks prior to harvest increased fruit firmness and reduced color. Gibberellic acid sprays reduced pitting when the disorder was present (1974 and 1976) or where the fruit were bruised. Mechanical bruising of cherries increased the incidence of pitting. Surface pitting of sweet cherries may be caused by bruising but fruit characteristics (% soluble solids, size and firmness) can indicate whether or not pitting may occur on bruised fruit.**

Surface pitting has become a major problem, which lowers the fresh market quality of cherries from the Pacific Northwest. The disorder is rarely seen on fruit on the tree. It usually develops after 4-10 days in cold storage and is characterized as one or more irreguiar hardened depressions occurring anywhere on the fruit but predominantly on the shoulders (8). Investigations involving pitting have included storage tests of fruit (4, 8), fertilizer trials (10), leaf nutritional sprays (8), and mechanical injury (1, 2, 7). Since no real cause-and-effect relationship has been found we initiated a study to investigate effects of various postharvest treatments and possible relationships between various pre-harvest tree and fruit characteristics and surface pitting. We also examined the effects of preharvest sprays of GA_3 and GA_{4+7}, and bruising on their possible relations to surface pitting.

Materials and Methods

Postharvest. Fruit used in the postharvest investigations were obtained from 3 'Bing' cherry orchards and 1 'Lambert' orchard in the Mid-Columbia area in 1972, from 9 'Bing' and 8 'Lambert' orchards in 1974, and from 6 'Bing' and 8 'Lambert' orchards in 1978. All fruit were harvested at commercial maturity according to acceptable color standards. Ten mature trees were sampled in each orchard and after delays of 1.5 – 2.5, 4, 8, 12, and 24 hr at 21°C and 40% relative humidity, fruit were treated and stored. Only the 1.5 and the 24 hr delays were tested in 1974. Samples of 100 fruit per tree were treated with either no hydrocooling or immersion hydrocooling (mechanical refrigeration) for 6 min at 1° or 6° and then dipped in Captan-Botran (1.2 g/liter each chemical, 75 WP and 50 WP respectively). The potential interaction between bruising fruit before and after hydrocooling was examined in 1978. Samples were stored at 1° and 6° in unsealed polyethylene bags for 2 weeks in 1972 and 1974 and 1°C in 1978. At the end of this period, each fruit was scored for the incidence of pitting using the description of Porritt et al. (8) with the additional criterion that the tissues within the pit remain firm.

Orchard surveys. Table 1 gives an outline of the number of orchards and fruit sampled each year plus the chemical and bruise treatments. Table 2 gives an outline of the variables measured each year in the orchards used. Where applicable, analysis of variance was used to compare treatments. Extensive use was made of scatter diagrams in efforts to gain as much information as possible about relationships between variables. These efforts are summarized in Table 5 in the form of simple linear correlation coefficients. The multiple regression models presented in Table 6 were chosen to as nearly as possible reflect a consensus of the results of 6 years of intensive analysis. Many potential models were considered on the basis not only of R^2, but of their horticultural logic (both for inclusion and predictibility) and their statistical validity in the sense of the "randomness" of the errors of prediction. In any given year, other satisfactory models with higher R^2 values were found. The complexities of the interrelationships among potential explanatory variables makes detailed interpretation of these models of questionable value.

Results and Discussion

Postharvest (1972 and 1974). Time delay prior to cooling

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[2]This research was supported in part by the Washington Tree Fruit Research Commission, the Washington Soft Fruit Commission, and the Wasco County Fruit and Produce League.
[3]Associate Professors, Mid-Columbia Experiment Station and Department of Statistics, Oregon State University, respectively.
[4]Gratitude is expressed to Diamond Fruit Growers, Inc., Hood River, OR, for the use of their sweet cherry packing line.