THE EFFECT OF NITROGEN, POTASSIUM AND SADH ON YIELD, QUALITY AND VEGETATIVE GROWTH OF SOUR CHERRY (*Prunus cerasus* L., var. Montmorency)

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

THOMAS FLOYD CROCKER

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THESIS

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THE EFFECT OF NITROGEN, POTASSIUM AND SADH ON
YIELD, QUALITY AND VEGETATIVE GROWTH
OF SOUR CHERRY (Prunus cerasus L., var.
Montomorency)

presented by

Thomas Floyd Crocker

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ABSTRACT

THE EFFECT OF NITROGEN, POTASSIUM AND SADH ON YIELD, QUALITY AND VEGETATIVE GROWTH OF SOUR CHERRY (*Prunus cerasus* L., var. Montmorency)

By

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Field plots to establish nitrogen levels for sour cherry were initiated in the spring of 1967. Initial rates of 0, 1.5 and 3 pounds of NH_4NO_3 per tree were applied around the periphery. Nitrogen rates were increased each year until 1970 when 0, 3 and 9 pounds of NH_4NO_3 per tree were applied. These differential nitrogen plots were split with a potassium application as 0 or 2 pounds KCl per tree in 1968. These potassium rates were reapplied annually through 1970. At two weeks after full bloom in 1969 and 1970, the nitrogen and potassium plots were split with a SADH application of 4000 ppm.

Total yield was increased by 25 pounds per tree with nitrogen application in 1968 and by 35 pounds per tree in 1969. No yields were recorded in 1970. Increased nitrogen had no significant affect on fruit color, did not result in a softer cherry nor did it increase size. There was a significant increase in leaf nitrogen for high nitrogen application in

both 1969 and 1970. In 1970 a leaf nitrogen value of 2.65% was found for the low and 2.83% for the high nitrogen application rate.

Fruit removal force, size, yield or firmness was not effected by potassium treatments. A leaf potassium value of 1.13% was found for non-treated and 1.31% for potassium treated trees.

Fruit color and firmness was increased early in the season with SADH treatment in both years. The increased cherry firmness was maintained in a processed product in 1970, however, increased fruit color did not.

SADH treatment showed an apparent decrease in terminal growth on lower branches. However, trunk circumference measurements showed no decrease resulting from SADH treatment. A three-fold increase in SADH fruit residue was found with two years application. However, the average 11 ppm SADH residue from fruit that received SADH for two years was far below the 50 ppm tolerance set by FDA.

A firmer processed product was obtained with a .2% calcium chloride solution plus a precook at 140 F for 10 minutes. SADH treated fruit also resulted in a firmer processed product.

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By

Thomas Floyd Crocker

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INTRODUCTION

Michigan produces over 65% of the national tonnage of sour cherries. Nearly the entire crop is processed as frozen, hot-pack (canned) or brined cherries. It is essentially of one variety--Montmorency--which has a prime harvest period of two or, at most, three weeks depending on climate.

Mechanization of harvesting and field handling of sour cherries has made it possible to harvest the crop during the short period of desirable quality. However, processing plants do not have the capacity to handle above average crops. As a result, the harvest period may be extended in many years. This extension of the harvest period results in overmature fruit that may be too large and soft and result in a poor quality processed product.

Although it is normal for a cherry to continue enlargement and softening with delayed harvest, the use of nitrogen fertilizers are often given credit for this. Also, a cherry tree will normally have some light colored fruit which is associated with the use of nitrogen fertilizers. Low levels of potassium have been, likewise, reported to influence size and color of cherries.

Recent studies (11,44,48) of SADH* applications have reported alleviation of many of these factors (size, softness, color) associated with poor quality. Commercial use of SADH was initiated in 1970.

This study was to determine (1) if high nitrogen application would produce poorly colored, large, soft cherries, (2) if added nitrogen would enhance or reduce the response of sour cherries to SADH (3) to determine if added potassium would affect fruit quality and (4) to evaluate the influence of these factors on processed cherry quality.

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*SADH - (Succinic acid 2, 2-dimethyl hydrazide) A product of UNIROYAL Chemical Company, Division of UNIROYAL, Inc., Naugatuck, Connecticut marketed as Alar 85.

REVIEW OF LITERATURE

Sour Cherry Industry
(Prunus cerasus L., var. Montmorency)

In Michigan, sour cherry is exceeded only by apple in acreage, yield and dollar value. However, the industry has been severely depressed in terms of grower profits in recent years. The depression of grower profits has been attributed to many causes mainly--spring frost damage plus other climatic factors--wind, hail, etc.--which lead to extremely wide production fluctuations (38,39).

Many feel (15,18,39) that a sour cherry market potential exists if the average annual crop of 200 million pounds is continuous. The industry can not endure two years like 1964 and 1965 when there was a full crop each year and 20% of the cherries were not harvested in 1964 and 10% in 1965. More uniform annual production is needed to provide better competition with other fruits plus building confidence in the industry.

Proper sour cherry maturity and quality are very important to the processor (18). Proper fruit maturity in any given orchard is optimum for only ten to fourteen days. With production limited to the Montmorency variety, growers are required to harvest their total crop in two weeks or

less (22). When cherries are harvested immature, the stem remains firmly attached or the pit pulled at harvest and the fruits are low in color. When harvested overmature, the cherries are soft and do not pit properly causing assorted problems in the processing plant (18).

Mechanical harvesting and field handling has enabled the grower to harvest the crop in the desired period. However, processing plant capacity is not sufficient to handle the volume of cherries from a full crop in such a short period of time. This problem has been greatly aggravated in recent years with the widespread use of mechanical harvesting.

Adding to these problems are variations in fruit color, firmness and size due to year to year variations in climatic conditions, normal characteristics, plus over vigorous trees (17,18).

The future of the sour cherry industry rests on its ability to alleviate wide production and price fluctuations (38) plus increased efficiency to maintain annual production to satisfy or increase the demand of 1.3 pounds per capita consumption (15,40).

Mineral Nutrition

Research to establish the nutritional requirement of sour cherries is quite limited, when compared to investigations of other fruit tree crops. There is evidence to

indicate (7,8,56) that the sour cherry tree probably has the same nutritional requirements with similar limits as other tree fruit crops.

Early work (7) showed little response to added fertilizer applications, in particularly potassium and phosphorus. Later, other investigators (8,12,13) have found some responses to potassium and phosphorus after the trees are mature.

Leaf analysis has come into widespread use as a method of expressing nutritional requirements of tree fruits as a leaf nutrient composition value. Kenworthy (30) has advanced standard leaf composition values for cherries as: Nitrogen - 2.95%, Potassium - 1.67%, Phosphorus - .25%, Calcium - 2.09%, Magnesium - .68%. Cain (8) reported standard values of Nitrogen - 3.0%, Potassium - 1.50%, Phosphorus - .20%, Calcium - 1.0%, Magnesium - .40%. The above values are for optimum performance if all other factors are adequate and favorable for growth.

Nitrogen

Many visual symptoms of nitrogen supply have been advanced by Kenworthy (26) and Gilbert (19); i.e. spur formation, terminal growth, branching and general growth habit of the tree.

Gilbert (19) suggested terminal growth of 18 inches with a diameter of 18 mm as typical for a healthy cherry tree. Kenworthy (26) indicated that growth of 10 to 20 inches was adequate for terminal growth with over 20 inches being too vigorous with few spurs and no fruit buds initiated. Several methods of determining tree vigor have been advanced by Wilcox (53,54,55). His studies suggest that terminal shoot growth plus trunk circumference could be used to obtain a reliable indication of tree vigor.

Tukey and Tukey (46) reported that size of spur leaves could be increased with nitrogen fertilization. Nitrogen also delayed maturity about ten days with no detriment to color. They also stated that high nitrogen tended to reduce sugar accumulation as does heavy pruning and this resulted in poorly colored cherries. Curwen (13) also, reported that high nitrogen delayed maturity.

Kennard (23) found that nitrate of soda in quantities up to 350 pounds per acre applied on or before August 1st did increase low temperature injury to trees. Nitrogen has been found to give the greatest increases in yield of any element (7,8,19,25). Drake (17) and Mitchell et al. (41) stated that excessive pruning led to excess vigor and soft fruit.

Cain (8) increased nitrogen applications as NH_4NO_3 from 2 to 6 pounds per tree from 1954-1960 and increased production 44%. In 1961 Cain (9) stated that perhaps some manipulation of the harvest schedule could be achieved by differential nitrogen fertilization or schedule harvest according to fertility level, i.e. harvest high nitrogen trees last.

Harrington (29) found that fruit size was larger on sudangrass covercrop plots that ryegrass-vetch plots, and that low nitrogen produced slightly larger cherries than medium or high nitrogen. Kenworthy (28,29) found no effect of nitrogen carriers on size of cherry fruit. He found, also, that size was not consistently related to any one nutrient element. Mitchell, et al. (41) stated that excessive nitrogen caused large, soft cherries which were difficult to pit. Taylor and Mitchell (45) reported that sprays of fixed copper and hydrated lime increased fruit size at first harvest and that ferbam plus parathion increased fruit size at the last sampling date. Bryant (7) found that nitrogen gave no significant increase in fruit size at rates of 80 pounds of actual nitrogen per acre.

Kenworthy (25,29) stated that nitrogen and complete fertilizers with straw mulches reduced soluble solids of cherries. This decrease was associated with an increase in leaf nitrogen. Taylor (45) found a significant correlation

between soluble solids and total solids of the cherry fruit. Soluble solids and total sugar, also, increased during the first 14 days of the 29 days of the commercial harvest period. Kenworthy and Mitchell (24) suggested that soil management practices, such as mulching and applying nitrogen, increase available moisture and nitrogen may be expected to reduce soluble solids of the fruit at harvest.

Potassium

Kwong et al. (33) found that potassium had no effect on soluble solids of sweet cherries and that fruit size was improved as leaf potassium approached 1.25%. Parups, et al. (43) reported that high levels of sulfate or chloride reduced dry weight and shorten growth of sour cherry. Dilley, et al. (16) also found that increasing the supply of chloride or sulfate depressed growth of young cherry trees. Increasing the level of chloride in the nutrient solution increased manganese in cherry leaves.

Mulching was shown to increase potassium in the leaves of trees when compared to unmulched trees (25). Cline (12) reported that potassium did not increase growth or yield even though an increase in leaf potassium was reported. Cain (8), however, did find an increase in yield with increased potassium. Gilbert and others (8,19) have shown that increasing potassium increased the yield of cherries.

Baker (2), Cline (12) and Gilbert (19) reported that potassium deficiency resulted in lower yields with reduced terminal growth and small leaves. Zubriski, et al. (56), in a study of potassium content of sour cherry leaves in relation to leaf curl and to exchangeable potassium in the surface soil, found leaf curl when soil potassium was below 200 pounds per acre. A correlation coefficient of .936 for a linear relationship was found between leaf potassium and soil potassium.

Curwen (13) reported that increasing leaf potassium resulted in soft cherries with higher juice loss upon pitting and a reduced content of water insoluble pectic substances. A reduced fruit calcium was associated with high potassium levels. It is suggested that high potassium induced calcium deficiency in the fruit, resulting in less water insoluble pectic content; therefore, softer fruit.

Fruit color was shown to decrease with added potassium and nitrogen treatments by Kenworthy (29). Cline (12) and Archibald reported that fruit from potassium treated trees were darker in color and larger than non-treated fruit.

Fruit Removal Force (FRF)

Cain (10) studing mechanical harvesting of cherries, has related harvesting effeciency to fruit retention force (FRF) of the pedicel. His studies indicated that cherries with a FRF of 368 grams or greater could not be easily harvested with mechanical harvesters. Unrath (47), after

comparison of FRF with observed case of mechanical harvesting suggested that the maximum force for commercial harvesting would be 500 grams.

SADH (Succinic Acid 2,2-Dimethyl Hydrazide)

Unrath, et al. (48) studied the effect of SADH on cherry fruit maturation, fruit quality and vegetative growth. He found that SADH applied two weeks after full bloom at 4000 ppm gave the most desirable response. SADH was reported to decrease FRF sufficiently to start commercial harvest one week early. Fruit color and firmness also were enhanced by the SADH application and this enhancement of fruit color and firmness was carried over in both a canned and frozen product.

Dekazos, et al. (14) showed that SADH treated fruit had an increase in total anthocyanin pigment and that anthocyanin biosynthesis was altered by the treatment. The most evident effect of SADH on cherry fruit color was a change in the ratio of two pigments. Chaplin, et al. (11) determined that SADH promoted anthocyanin development of sweet cherries and postulated that SADH acted directly on the anthocyanin and sugar biosynthesis enzyme systems.

SADH has been reported to reduce internode length and terminal growth of cherries at 4000 ppm and increase flower bud initiation (11,31,48). Unrath (47) suggested that there was a trend toward increasing leaf nitrogen as SADH

concentrations increased. This effect could be the result of reduced nitrogen utilization because of growth reduction by SADH. He, also, found a reduction in fruit size at harvest with SADH application.

Ryugo (44) and others (11,48) have shown, through SADH residue analysis, that fruit residue values were linear to concentrations applied.

Processing

Bruising has been one of the foremost problems in harvesting and marketing of sour cherries (51,52) even before the advance of mechanical harvesting. Water cooling and handling of cherries has been used effectively to reduce bruise damage of mechanically harvested cherries. When harvesting was carried out with proper equipment and handling procedures, bruising was minimized and a quality product was maintained (18). Marshall, et al. (40) reported that soaking cherries in running tap water for more than twelve hours at 57 F resulted in considerable loss of fruit due to cullage, loss of soluble solids, color and an increase in skin toughness. Whittenberger and Hills (50) using unbruised cherries in water soak reported an increase in weight and firmness with a decrease in soluble solids. Bruised cherries did not gain in weight. Both bruised and unbruised cherries became firmer with loss of soluble solids when soaked at temperatures of

34 F and 70 F. Hills, et al.(21) found that unbruised cherries gained weight during the cold water soak, but the final yield of the canned fruit from both bruised and unbruised samples was not statistically different. The gain of the unbruised cherries was lost during processing.

LaBelle and Mayer (34) and LaBelle (36) reported that the degree of bruising, increased maturity and lapse time between harvesting and processing tended to decrease firmness and drained weight. No difference was found between the firming effect of holding in 40 F or 80 F air or soaking in 40 F or 80 F water. However, when the higher temperatures were used, there was an increase in scald. Floate (18) reported preliminary work that showed specific temperature range of 50 F to 55 F for firmness development with colder temperatures inhibiting chemical reactions necessary for firming.

Bedford and Robertson (6) also showed that delaying harvest resulted in softer fruit, lower processed yield with an increase in water and juice loss. Soluble solids and color were increased by the late harvest. In other work (3) they found no significant differences in drained weights between orchards or years with spray treatments, fungicidal mixtures, and wax emulsion. Copper sprays resulted in cherries of slightly higher drained weight. In a later study of factors affecting the drained weight of canned cherries, Bedford and

Robertson (34) could find no relationship between soluble solids, temperature of soak water and drained weight of the cherries. Soak time varied from 0 to 48 hours.

The effect of calcium on firming of plant tissue has been reported by Kertesz as early as 1939 (32). Bedford and Robertson (5) could find no effect of calcium on drained weight of canned cherries. The calcium treatments were .05, .10 and .15 percent calcium chloride solutions with soaking at 2 C for 6 to 24 hours and addition of calcium chloride to the pitted cherries before canning. However, tenderometer values of the canned cherries increased with greater calcium concentrations. LaBelle (37) with a preheat treatment at 140 F for 5 to 20 minutes plus addition of calcium up to .04% of final product reported 50 percent greater firmness. However, he reported a superior drained weight with the conventional cold-fill process with no calcium addition.

Whittenberger (49) suggested that the processed cherry may be looked upon as a cellular sponge, whose holding capacity is dependent upon the maintenance of the cell structure. Therefore, factors which weaken the cell walls would decrease drained weight and factors which strengthen the cell wall would increase drained weight. Factors in the latter group would include bruising, aging, and calcium treatments in both soak water and pitted fruit.

METHODS AND MATERIALS

Location of Field Plots

Experimental plots were located in Northern Michigan's fruit belt on Leelanau Penninsula. The orchard belonged to Mr. Raymond Alper of Lake Leelanau, Michigan. Prior to initiation of the experiment in 1967 the twelve-year-old trees had not been pruned for mechanical harvesting.

Experimental Design

The experimental design was a split-split plot with nitrogen application being split for potassium in 1968-1970 and SADH in 1969 and 1970. All sub-sub plots consisted of three tree treatments with four replications. Statistical significances between means was tested by use of Duncan's Multiple Range Test.

Treatment Applications

Nitrogen applications were started in the spring of 1967 at 0, 1.5 and 3 pounds of NH_4NO_3 per tree applied around the periphery of the tree. These rates were increased each year until the spring of 1970, when the rates were 0, 3 and

9 pounds of NH_4NO_3 applied to each treated tree. Each replicate contained fourteen trees. These rates will be referred to as low, medium and high application rates.

In the spring of 1968, the plots of 14 trees receiving nitrogen were split with KCl treatments of 0 or 2 pounds of KCl spread around the periphery of the treated trees. A border tree was left between the potassium rates. Thus, each sub plot contained six trees. These same rates of potassium were reapplied annually through the spring of 1970.

Two weeks after full bloom in 1969 the nitrogen and potassium treatments were split with an application of 4000 ppm SADH, (250 gallons per acre) applied with a high pressure sprayer mounted on the back of a truck. This treatment was repeated the following spring with the dilute application being made by the grower with an air blast orchard sprayer. Each sub-sub plot contained three trees.

Harvest Measurements

No harvest measurements were made in 1967 because of spring frost. Beginning at harvest in 1968, two weeks before harvest in 1969 and one week before harvest in 1970, several parameters of maturity were measured at weekly intervals. FRF and firmness measurements were taken in the field.

Fruit Removal Force (FRF)

The FRF was measured in 1969 starting at two weeks before harvest, and one week before harvest in 1970. Twenty fruit were selected randomly around the outer edge of the tree at a 4-to 7-foot height. A model L-1000-M, Hunter push-pull mechanical force gauge,[1] was used for all FRF measurements. A claw was fitted to the gauge so that the fruit could be pulled from the pedicel and this separation force was recorded.

Fruit Firmness

Twenty fruits were selected in the same manner as for FRF. Fruit firmness was determined by taking one reading on the cheek of each fruit with a type 00 Durometer.[2]

The Durometer had a 2.5 mm diameter plunger, which extended 3.0 mm from the base of the instrument. This plunger was pressed against the fruit until the cheek and base of the instrument were in contact. The degree of retraction of the plunger into the base was read on a scale of 0 to 100, with a reading of 100 being equal to 4 ounces of force.

After recording FRF and firmness of the fruit, a pint sample of fruit was picked at random around the outside of the tree. These samples were used to evaluate the following parameters:

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[1]Manufactured by: Hunter Spring, Division of Ametek, Inc., Hatfield, Penn.

[2]Manufactured by: Shore Instrument and Mfg. Co., Inc., Jamaica, N.Y.

Fruit Color

Fruit color was determined by randomly selecting 20 fruits and taking a ¼ inch disc of epidermal tissue from the cheek of each fruit. These 20 disc were placed in 25 ml of 0.5% oxalic acid solution. After storage at 40 F for one week or longer so that color equalization could be completed, the samples were brought to 50 ml with 0.5% oxalic acid and filtered. The absorbance of the solutions were read at 515 nm with a Beckman B Spectrophotometer.

Size of Fruit

Size of fruit was taken in 1968 by counting the number of fruit in a 50 gram sample. In 1969 and 1970 fruit size was determined by weighting a 50-fruit sample.

Soluble Solids

Soluble solids were taken by crushing ten randomly selected cherries from the color sample. Readings were made with a hand refractometer.

Total Yield

Total yields were taken in 1968 and 1969 by weighing all fruit from each tree at harvest. All weekly parameters were taken at harvest. All plots were mechanically harvested with a self-propelled Friday Harvester.[3]

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[3]Manufactured by: Friday Tractor Co., Hartford, Michigan.

Yield data was not obtained in 1970 because of the light crop and adverse weather conditions--wind damage late in the season.

Growth Measurements

Terminal Growth

The length of ten randomly selected shoots was recorded with selection being at a height of four to seven feet on the tree. These measurements were made during the dormant season starting in 1967 and continuing through 1970.

Trunk Circumference

Starting in the fall of 1967, trunk circumference of each tree was measured at a height of two feet and marked with yellow paint. This measurement was taken each year through 1970 using the same location.

Leaf Analysis

Leaf samples were taken in mid-July each year from 1967-1970. Nitrogen was determined by modified Kjeldahl; potassium by flame photometer; phosphorus, sodium, calcium, magnesium, manganese, iron, copper, boron, zinc and aluminum were determined spectrographically by use of a photoelectric spectrometer in accordance with procedures described by Kenworthy (27).

Processing Studies

At harvest in 1970, a 20 pound sample of each treatment was picked from each of two reps two days apart. These samples were placed in a 12-hour cold water soak prior to processing.

After the soak period, all fruit was passed over a sorting belt where culls, stems and debris were removed and weighed. Sorted fruit was weighed before pitting. The pitted fruit was allowed to drain five minutes and weighed. The pits were drained for ten minutes and then weighed. From these measurements juice loss during pitting was calculated.

Four No. 303 and two No. 10 cans were filled with 12 ounces and 88 ounces of pitted cherries respectively.

The No. 303 cans were covered with hot water, exhausted for seven minutes, sealed and processed for eight minutes at 210 F. After processing the filled cans were rapidly cooled in cold-water and then stored at 50 F for later evaluation.

The No. 10 cans were filled with hot water and exhausted to a center temperature of 150 F sealed, processed in 210 F water for 20 minutes, cooled and stored.

Calcium Chloride Treatment

The effect of adding calcium chloride to pitted cherries was studied as follows:

Control

(A) Eight 12 ounce lots of SADH treated and non-treated pitted cherries were placed in No. 303 cans, covered with hot tap water, exhausted to 180 F in seven minutes, sealed and processed for ten minutes at 210 F. The cans were then cooled and stored.

(B) Same as above except hot distilled water was used to cover the cherries.

Treated

(A) Two ounces of hot 0.2% calcium chloride solution was placed in the bottom of eight No. 303 cans for both SADH treated and non-treated fruit. Twelve ounces of pitted cherries were added and covered with hot 0.2% calcium chloride. The cans were then maintained at 140 F for ten minutes, exhausted for seven minutes, sealed and processed as above.

(B) Eight 12 ounce samples of pitted cherries from each treatment were weighed in sauce pans and nine ounces of hot 0.2% calcium chloride was added. Temperature was brought to 140 F while stiring the sample, this temperature being held for ten minutes. The fruit was then transferred to No. 303 cans, exhausted, sealed and processed as above.

Evaluations of Processed Fruit after Storage

Both the No. 303 and No. 10 cans were stored for four months at 50 F. After four months two cans of each treatment were evaluated as follows:

Drained Weight

The cans were opened, the contents placed on 8-mesh screen and allowed to drain for two minutes. Weight of drained cherries was recorded.

Juice Color

A 25 ml aliquot of the drained juice was placed in a bottle containing 25 ml of 0.5% oxalic acid. This solution was allowed to settle, filtered and 10 ml diluted with 50 ml of 0.5% oxalic acid and absorbancy at 515 nm recorded using a Beckman B Spectrophotometer.

Fruit Color

Color of the drained fruit was determined using a Hunter Lab Color and Color Difference Meter, Model D25[4], with a 4-inch aperture.

Firmness

Firmness of the drained fruit was determined with a L.E.E. Kramer Shear Press Model SP-12 IMP[5], using a 150 gram sample of cherries.

Residue Analysis

Residue analysis for SADH in fresh fruit were determined on all SADH treatments in 1969 and 1970. The procedure

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[4]Manufactured by: Hunter Associates Laboratory, Fairfax, Va.

[5]Manufactured by: L.E.E. 625 N.Y. Ave. N.W., Washington, D.C.

described by Ryugo (44) was used. Samples were taken at the last weekly sampling date.

SADH Survey

In 1970 a survey was made of 25 Michigan growers that had applied SADH during the 1970 season. Fruit and leaf samples were taken at harvest for residue and mineral analysis respectively. At the time of sampling, information was obtained as to time of application, rate of application, weather conditions and any pesticides applied in combination with the SADH.

RESULTS AND DISCUSSION

Total Yield

Yield

Total yields were taken in 1968 and 1969 by weighing all mechanically harvested fruit from each tree. High nitrogen applications in 1968 increased yield by 26 pounds per tree over trees receiving the low level of nitrogen (Table 1). In 1969, high nitrogen increased yield by 35 pounds per tree. Both of these increases were highly significant and are supported by many other workers (8,19,25). The added income resulting from high nitrogen indicated that the point of diminishing returns had not been reached at 900 pounds of NH_4NO_3 per acre.

Potassium applications did not result in increased yields in either 1968 or 1969 (Table 1). SADH application resulted in an increase of 7.3 pounds of fruit per tree compared to non-treated trees (Table 1). This was not significant at the 5% level. However, if a standard minimum shaking force had been used when harvesting there may have been a much greater recovery of SADH treated fruit because of the decreased fruit removal force (Table 12). The operators of the equipment could easily distinguish the SADH treated trees because of the ease of removal of the fruit.

TABLE 1.--Yield of Cherries from Nitrogen, Potassium and SADH Treatments in 1968 and 1969.

	Yield Pounds Per Tree[1]			
	1968	1969	SADH ppm	1969
Nitrogen[2]				
N_0	91.6[a]	96.0[a]		
N_1	102.1[ab]	113.0[b]	0	109.9
N_2	117.5[b]	131.6[c]	4000	117.2
	*	*		NS
Potassium[3]				
K_0	111.6	112.7		
K_1	95.9	114.3		
	NS	NS		

[1]Harvest with Friday Mechanical Harvester.

[2]0, 1.5, 3 pounds in 1968; 0, 3, 6 NH_4NO_3 in 1969.

[3]0, 2 pounds KCl in 1968 and 1969.

*Significant at 5% level.

NS Values not significantly different.
Values followed by unlike letters significant at 5% level.

The interactions of nitrogen x potassium and nitrogen SADH were not significant. However, the interaction between nitrogen and SADH suggested that SADH was more effective at low levels of nitrogen than at the higher rates (Table A1).

Mineral Nutrition

Leaf Nitrogen

When differential rates of nitrogen were initiated in the spring of 1967, there was no difference in nitrogen content of leaf samples taken in July of that year (Table 2). Leaf samples in 1968 again indicated no significant difference in nitrogen composition. Rates of nitrogen application were increased in 1969 and leaf nitrogen was increased significantly in medium and high rates of nitrogen application over low nitrogen. Rates were increased again in 1970 and a significant differential in leaf nitrogen was established for the three rates. This indicates that responses to increased nitrogen may not be reflected immediately unless the increase is greater than normally used. In 1970, high nitrogen resulted in a leaf nitrogen value of 2.83% which is the optimum reported by Kenworthy (26).

Potassium levels had no effect on leaf nitrogen values in 1968, 1969 or 1970 (Table 2). The same was true for SADH at 4000 ppm applied in 1969 and 1970.

There were no significant interactions of nitrogen x SADH or nitrogen x potassium. Interactions of nitrogen x SADH (Table A2) do not suggest that SADH increased leaf nitrogen as reported by Unrath *et al.* (47).

TABLE 2.--Nitrogen, Potassium and SADH Effect on Leaf Nitrogen 1967, 1968, 1969 and 1970.

	Leaf N%			
	1967	1968	1969	1970
Nitrogen[1]				
N_0	2.71	2.61	2.62[a]	2.65[a]
N_1	2.75	2.57	2.77[ab]	2.73[b]
N_2	2.71	2.64	2.77[b]	2.83[c]
	NS	NS	*	**
Potassium[2]				
K_0	--	2.64	2.73	2.74
K_1	--	2.58	2.72	2.74
		NS	NS	NS
SADH ppm				
0	--	--	2.73	2.72
4000	--	--	2.71	2.75
			NS	NS

[1]0, 1.5, 3 pounds NH_4NO_3 in 1967, 1968; 0, 3, 6 pounds in 1969; 0, 3, 9 pounds in 1970.

[2]0, 2 pounds KCl in 1968, 1969 and 1970.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

Values followed by unlike letters significant at 5% level.

Leaf Potassium

Potassium treatments were started in the spring of 1968 with two pounds of KCl applied to each treated tree. As indicated in Table 3, nitrogen levels had no effect on leaf potassium. There was no difference in uptake of potassium for the different application rates of nitrogen. The interaction between nitrogen and potassium applications was not significant.

The first two years of potassium treatment did not significantly increase leaf potassium (Table 3). However, there was a significant increase in 1970. The level of potassium (1.31%) associated with potassium application is adequate, but Kenworthy recommends a leaf potassium of 1.50% for optimum growth. This indicates that potassium should be increased even more to provide an adequate evaluation of response.

SADH application in 1969 and 1970 did not enhance or reduce leaf potassium (Table 3). There were no significant interactions of SADH, nitrogen or potassium levels in relation to leaf potassium.

Growth Measurements

Terminal Growth

Terminal growth measurements from randomly selected branches were taken during the dormant season for each year

TABLE 3.--Nitrogen, Potassium and SADH Effect on Leaf Potassium 1967, 1968, 1969 and 1970.

	Leaf K%			
	1967	1968	1969	1970
Nitrogen[1]				
N_0	1.05	1.08	1.25	1.17
N_1	1.07	1.00	1.20	1.23
N_2	1.06	1.03	1.18	1.26
	NS	NS	NS	NS
Potassium[2]				
K_0	--	1.00	1.19	1.13
K_1	--	1.07	1.23	1.31
		NS	NS	**
SADH ppm				
0	--	--	1.22	1.25
4000	--	--	1.20	1.19
			NS	NS

[1]0, 1.5, 3 pounds NH_4NO_3 in 1967, 1968; 0, 3, 6 pounds in 1969; 0, 3, 9 pounds in 1970.

[2]0, 2 pounds KCl in 1968, 1969, 1970.

**Significant at 1% level.

NS Values not significantly different.

from 1967-1970. Measurements made after one year of nitrogen application (Table 4) showed that low nitrogen treatments had the most terminal growth. The amount of terminal growth decreased each year for low nitrogen thereafter. High and medium nitrogen applications did not show an increase in terminal growth over low nitrogen rates in any of the four years. However, the decrease in terminal growth from 1967-1970 was 5.5 inches for low nitrogen, 3.32 inches for medium nitrogen and only 2.50 inches for high nitrogen. This may reflect inadequate sampling. However, cherry trees usually show a decrease in terminal growth on lower branches as they become older. Kenworthy (26) and Gilbert (19) suggest ten to twenty inches of growth typical; however, no terminal growth measurements in any of the four years approached these figures. If measurements had been made on branches in the top of the tree instead of from the ground, a closer relationship to desired rate of growth may have been possible.

Measurements for potassium treatments showed no difference in terminal growth due to potassium applications. The amount of growth was of the same magnitude as the nitrogen treatments.

SADH application at 4000 ppm in 1969 and 1970 resulted in a significant decrease in terminal growth (Table 4). The first year of application there was a 25.5% reduction in terminal growth. There was a 55% reduction in terminal growth when SADH was applied for two years indicating a carry over effect of SADH.

TABLE 4.--Terminal Growth Measurements for Nitrogen, Potassium and SADH Treatments in 1967, 1968, 1969 and 1970.

	Terminal Growth (Inches)[1]			
	1967	1968	1969	1970
Nitrogen[2]				
N_0	8.30[a]	7.61	5.02	2.79
N_1	6.20[ab]	7.27	4.74	2.88
N_2	6.82[b]	6.88	4.13	3.32
	*	NS	NS	NS
Potassium[3]				
K_0	--	7.40	4.50	3.00
K_1	--	7.03	4.75	2.99
		NS	NS	NS
SADH ppm				
0	--	--	5.30	4.13
4000	--	--	3.95	1.86
			**	**

[1]0, 1.5, 3 pounds NH_4NO_3 in 1967, 1968; 0, 3, 6 pounds in 1969; 0, 3, 9 pounds in 1970.

[2]0, 2 pounds KCl in 1968, 1969, 1970.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

A significant nitrogen x SADH interaction was apparent in 1970 (Fig. 1). Two yearly applications of SADH at 4000 ppm prevented the increase in terminal growth expected from an increase in nitrogen levels.

Trunk Circumference

Nitrogen levels were started in 1967 at the rate of 0, 1.5 and 3 pounds NH_4NO_3 per tree and increased to 0, 3, and 9 pounds per tree by 1970. Table 5 indicates that high nitrogen did not result in a significant increase in trunk circumference until 1970. Only after four years of high rates of nitrogen was there a significant response in trunk circumference reflecting an increase in vigor. This increase in vigor was not evident in terminal growth measurements.

Neither potassium nor SADH had a significant effect on trunk circumference. No significant interactions were apparent.

Harvest Measurements

Fruit Firmness

Fresh fruit firmness measured on the tree at harvest in 1968, showed no increase or decrease in firmness due to nitrogen or potassium treatments (Table 6). Firmness at three weekly periods starting two weeks before harvest in 1969 again indicated that nitrogen and potassium treatments had no effect

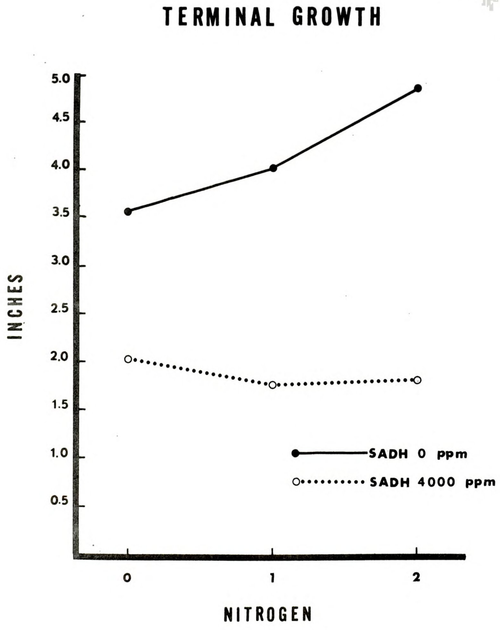

FIGURE 1.--Nitrogen x SADH Interaction in Relation to Terminal Growth 1970.

TABLE 5.--Trunk Circumference Measurements for Nitrogen, Potassium and SADH Treatments in 1967, 1968, 1969 and 1970.

	Trunk Circumference (Inches)			
	1967	1968	1969	1970
Nitrogen[1]				
N_0	16.75	16.96	18.10	18.98[a]
N_1	16.60	17.09	18.60	20.52[b]
N_2	16.91	17.73	19.55	20.39[b]
	NS	NS	NS	*
Potassium[2]				
K_0	--	17.76	18.96	19.93
K_1	--	16.75	18.53	19.98
		NS	NS	NS
SADH ppm				
0	--	--	18.91	20.19
4000	--	--	18.59	19.74
			NS	NS

[1] 0, 1.5, 3 pounds NH_4NO_3 in 1967, 1968; 0, 3, 6 pounds in 1969; 0, 3, 9 pounds in 1970.

[2] 0, 2 pounds of KCl in 1968, 1969 and 1970.

*Significant at 5% level.

NS Values not significantly different.

TABLE 6.--Fruit Firmness as Related to Nitrogen and Potassium Treatment in 1968.

Nitrogen[2]	Firmness[1]	Potassium[3]	Firmness[1]
N_0	44.28		
N_1	46.25	K_0	46.59
N_2	45.20	K_1	45.20
	NS		NS

[1]Firmness readings on a scale of 0 to 100, 100 = 4 oz. of force.

[2]0, 1.5, 3 pounds NH_4NO_3 per tree.

[3]0, 2 pounds KCl per tree.

NS Values not significantly different.

on firmness of the fruit (Table 7). The same results were obtained for two weekly periods in 1970 (Table 8). High rates of nitrogen apparently did not produce soft cherries that reportedly interfered with pitting. Firmness measurements taken at harvests during the three seasons had very little variation between nitrogen and potassium levels. There was a decrease in firmness as the season progressed, but this has been well documented by others (12,56).

SADH treated fruit were significantly firmer at all weekly measurements in 1969 (Table 7) and in 1970 (Table 8). The SADH treatment maintained firmness as maturity advanced. In 1969 when the trees were mechanically harvested, one could easily distinguish the SADH fruit by use of a manual pressure test of the fruit prior to soaking.

TABLE 7.--Fruit Firmness as Related to Nitrogen, Potassium and SADH Treatments. Three Weekly Periods 1969.

Treatment	Firmness[1] Weeks 1	2	3
Nitrogen[2]			
N_0	53.4	51.9	51.8*
N_1	53.4	52.1	51.4*
N_2	53.0	52.1	51.4*
	NS	NS	NS
Potassium[3]			
K_0	53.2	51.1	51.7*
K_1	53.4	53.1	51.4*
	NS	NS	NS
SADH ppm			
0	52.7	51.1	51.0*
4000	53.8	53.1	52.0*
	**	**	**

[1]Scale of 0 to 100, 100 = 4 oz.

[2]0, 3, 6 pounds NH_4NO_3 per tree.

[3]0, 2 pounds KCl per tree.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

TABLE 8.--Fruit Firmness as Related to Nitrogen, Potassium and SADH Treatments Two Weekly Periods 1970.

Treatments	Firmness[1] Weeks 1	Firmness[1] Weeks 2
Nitrogen[2]		
N_0	59.0	57.9 NS
N_1	58.8	58.1 NS
N_2	58.4	58.1 NS
	NS	NS
Potassium[3]		
K_0	58.9	57.9*
K_1	58.6	58.1*
	NS	NS
SADH ppm		
0	58.0	57.2*
4000	59.1	58.8*
	**	**

[1]Scale of 0 to 100, 100 = 4 oz.

[2]0, 3, 9 pounds NH_4NO_3 per tree.

[3]0, 2 pounds KCl per tree.

*Significant at 5% level.

**Significant at 1% level.

NS Values no significantly different.

The SADH firming effect carried over in the processed product as indicated by (Table 18). SADH maintained firmness in both the No. 303 and the No. 10 can. Unrath (48) reported this and attributed the effect to increased resistance of the SADH treated fruit to softening.

Fruit Color

Fruit color of sour cherries at three weekly periods in 1969 showed no significant increase or decrease in color due to nitrogen levels (Table 9). The same was true for two weekly periods in 1970 when there was much more fruit color due to the season and other factors (Table 9). High nitrogen in both 1969 and 1970 resulted in slightly more fruit color at all weekly periods than low nitrogen. This would tend to disprove that high nitrogen applications necessarily resulted in poorly colored cherries as indicated by Mitchell and others (29,39).

An increase in potassium application did not increase fruit color for the first two weekly periods of 1969 (Table 9) but did significantly increase color at harvest (period 3). This increase in fruit color had been reported also by Cline (12). In 1970, just the reverse was true, except that the data was not significant. Potassium application caused a slight reduction in fruit color at both periods in 1970 (Table 9) and agreed with the results reported by Kenworthy (29).

TABLE 9.--Fruit Color of Nitrogen, Potassium and SADH Treated Fruit at Three Weekly Periods 1969, and Two in 1970.

	Fruit Color (Absorbance, 515 nm)				
	1969 Week			1970 Week	
	1	2	3	1	2
Nitrogen[1]					
N_0	.348	.461	.569*	.831	.811 NS
N_1	.372	.459	.583*	.862	.827 NS
N_2	.371	.491	.597*	.849	.859 NS
	NS	NS	NS	NS	NS
Potassium[2]					
K_0	.369	.475	.567*	.859	.842 NS
K_1	.358	.465	.599*	.835	.822 NS
	NS	NS	**	NS	NS
SADH ppm					
0	.328	.446	.567*	.817	.818 NS
4000	.399	.494	.599*	.877	.847*
	**	**	*	*	*

[1]0, 3, 6 pounds of NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

In 1969, potassium applications resulted in fruit with less color than non-treated at the first two periods, but color was greatly enhanced during the last weekly period of harvest.

SADH significantly enhanced fruit color in 1969 and 1970 except the last weekly harvest in 1970 when color equalization had occurred (Table 9). At first period in 1970 the fruit from the high nitrogen, potassium and SADH treatments had approximately the same amount of color indicating that these treatments had resulted in maximum color development.

SADH increased color over all treatments at the first sampling period in 1969. This increase in color development would allow harvest to be advanced five to seven days. Unrath (48) reported this advancement in color development.

In 1969, SADH application showed a significant increase in color as the season advanced. In 1970, however, color development was extremely rapid and there was no significant increase from one weekly measurement to the next.

Nitrogen x SADH interactions were not significant for either year. However, the interaction data (Table A3) suggest that SADH enhanced color development to a specific level but not in addition to other treatments (i.e. nitrogen) that might increase color.

Data from cherries processed in 1970 showed no significant difference between any of the treatments in retention of color in the processed (hot pack) cherry (Table 18). As shown (Table 10) high nitrogen application resulted in a slightly higher color of cherries in both the No. 303 and No. 10 cans and that low potassium also resulted in slightly more color than potassium treated fruit. SADH resulted in a slight increase in color. However, no treatment (nitrogen, potassium or SADH) caused a significant change in color (Table 10).

Fruit Removal Force (FRF)

Nitrogen applications, in 1969 did not affect FRF at the first two weekly periods (Table 11). However, at harvest there was a decrease in FRF required to separate the fruit from it's pedicel with the high level of nitrogen application. This decrease was significant at the 1% level. For all weekly periods in both 1969 and 1970, high nitrogen resulted in somewhat lower FRF than either low or medium nitrogen. In 1970, there was no statistically significant difference in FRF (Table 11). As indicated, there was a decrease in FRF as the season progressed for both years.

Levels of potassium had no effect on FRF at any of the three weekly periods in 1969 or at either of the two weekly periods in 1970 (Table 12). There was a decrease in FRF as maturity advanced.

TABLE 10.--Processed Fruit and Juice Color from Nitrogen, Potassium and SADH Treatments 1970.

	Fruit Color (Absorbance, 515 nm)		Fruit Color (aL/bL Ratio)
	#303 Can	#10 Can	#303 Can
Nitrogen[1]			
N_0	.209	.211	1.50
N_1	.211	.207	1.52
N_2	.217	.219	1.53
	NS	NS	NS
Potassium[2]			
K_0	.215	.214	1.57
K_1	.209	.210	1.47
	NS	NS	NS
SADH ppm			
0	.211	.217	1.46
4000	.213	.208	1.57
	NS	NS	NS

[1]0, 3, 9 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

NS Values not significantly different.

TABLE 11.--Effect of Nitrogen Levels on Fruit Removal Force at Three Weekly Periods in 1969 and Two Weekly Periods in 1970.

	Fruit Removal Force[1]				
	1969 Week			1970 Week	
	1	2	3	1	2
Nitrogen[2]					
N_0	437	367	394*a	290	227*
N_1	443	363	281*ab	268	226*
N_2	434	340	267*b	280	225
	NS	NS	**	NS	NS

[1] Grams

[2] 0, 3, 6 pounds NH_4NO_3 1969; 0, 3, 9 pounds 1970.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

At period one and period three in 1969, SADH at 4000 ppm, significantly reduced FRF over non-sprayed fruit. FRF was decreased, also, in 1970 by the SADH treatment (Table 12). The ease of removal of cherries from the SADH treatments would indicate that harvest could be advanced by three to five days as reported by Unrath (48).

There was a significant potassium x SADH interaction at harvest in relation to FRF in both 1969 and 1970 (Fig. 2, 3). This interaction indicates that SADH reduced FRF at the

TABLE 12.--Effect of Potassium and SADH on Fruit Removal Force at Three Weekly Periods in 1969 and Two Weekly Periods in 1970.

	Fruit Removal Force[1]				
	1969 Week			1970 Week	
	1	2	3	1	2
Potassium[2]					
K_0	431	362	281*	280	226*
K_1	446	349	280*	278	226*
	NS	NS	NS	NS	NS
SADH ppm					
0	453	336	290*	287	234*
4000	423	345	271*	270	218*
	*	NS	*	*	**

[1]Grams

[2]0, 2 pounds KCl per tree in 1969, 1970.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

lower potassium level but not at the higher level. Higher potassium seemed to reduce the effect of SADH on FRF.

Fruit Size

Data collected in 1968, 1969, and 1970 indicated that there was no difference in size due to nitrogen treatments (Table 13).

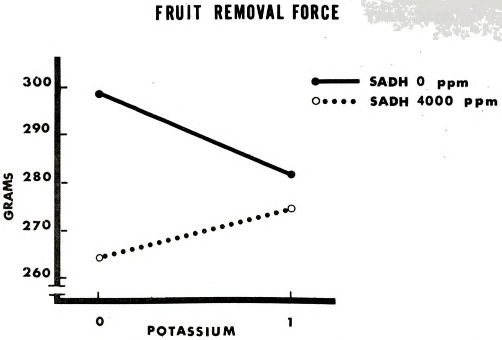

FIGURE 2.--Potassium x SADH Interaction in Relation to Fruit Removal Force Harvest 3, 1969.

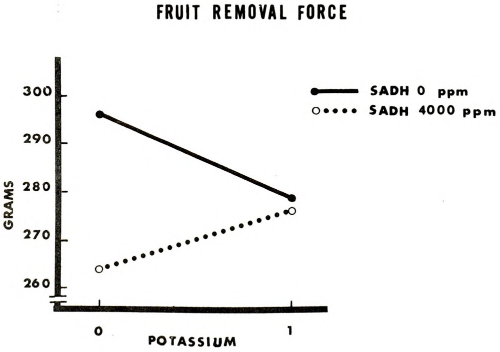

FIGURE 3.--Potassium x SADH Interaction in Relation to Fruit Removal Force Harvest 2, 1970.

Data for 1969 at three weekly periods indicate that high nitrogen resulted in a slightly smaller fruit than low nitrogen. The difference was not significant. This effect was shown also in 1970 at both periods. Harrington (29) found that low nitrogen produced larger cherries than higher nitrogen. This would suggest that high nitrogen levels are not responsible for large cherries.

There was a significant increase in fruit size as maturity progressed.

TABLE 13.--Fruit Size as Influenced by Nitrogen Treatments for 1968, 1969 and 1970.

	1968 Week	1969 Week			1970 Week	
	1	1	2	3	1	2
Nitrogen[2]						
N_0	4.29	4.0	4.5	4.8*	4.6	4.9*
N_1	4.64	4.8	4.6	4.9*	4.5	4.9*
N_2	4.38	3.7	4.3	4.6*	4.5	4.7*
	NS	NS	NS	NS	NS	NS

[1]Grams per fruit.

[2]0, 1.5, 3 pounds NH_4NO_3 per tree 1968; 0, 3, 6 pounds NH_4NO_3 per tree 1969; 0, 3, 9 pounds NH_4NO_3 per tree 1970.

*Significant at 5% level.

NS Values not significantly different.

Potassium treatments did not significantly affect fruit size (Table 14) in any of the three years. There was a trend at harvest in both 1969 and 1970 for fruit from the potassium treatment to be larger than non-treated fruit. Kwong (32) reported an increase in fruit size as leaf potassium levels approached 1.25%. In this study values of 1.31% (Table 3) leaf potassium for treated trees in 1970 showed no significant fruit size increase.

SADH sprays applied two weeks after full bloom at 4000 ppm in 1969 and again in 1970 showed no significant difference in fruit size (Table 14). No reduction in size was found with one or two years application. The second year of SADH application resulted in the same average size fruit of 4.8 grams as the one year application. No interactions were significant.

Soluble Solids

There was no statistical difference in soluble solids due to nitrogen treatments in 1969 and 1970 (Table 15). High nitrogen applications resulted in slightly higher soluble solids than low nitrogen in 1969 and 1970. This would indicate that higher nitrogen may have increased soluble solids. There was an increase in soluble solids as the season progressed in both 1969 and 1970 with the 1970 values being slightly higher than 1969.

TABLE 14.--Potassium and SADH Effects on Fruit Size 1968, 1969 and 1970.

	Size[1]					
	1968 Week	1969 Week			1970 Week	
	1	1	2	3	1	2
Potassium						
K_0	4.5	3.9	4.5	4.7*	4.5	4.8*
K_1	4.3	4.0	4.5	4.8*	4.5	4.9*
	NS	NS	NS	NS	NS	NS
SADH ppm						
0	--	3.9	4.5	4.7	4.6	4.8*
4000	--	4.0	4.4	4.8	4.5	4.8*
		NS	NS	NS	NS	NS

[1]Grams per fruit.

*Significant at 5% level.

NS Values not significantly different.

Potassium applications showed no effect on soluble solids in 1969 or 1970 (Table 16). The potassium treatment did show a slight increase in soluble solids in 1969 and 1970.

TABLE 15.--Effect of Nitrogen Levels on Soluble Solids of Sour Cherries at Five Weekly Periods in 1969 and 1970.

	%Soluble Solids[1]				
	1969 Week			1970 Week	
	1	2	3	1	2
Nitrogen[2]					
N_0	11.4	11.4	12.3*	12.1	12.5
N_1	11.4	11.7	12.4*	12.3	13.0
N_2	11.8	11.8	12.9*	12.6	13.1
	NS	NS	NS	NS	NS

[1]Measured by hand refractometer.

[2]0, 3, 6 pounds NH_4NO_3 in 1969; 0, 3, 9 pounds in 1970.

*Significant at 5% level.

NS Values not significantly different.

Soluble solids were not significantly changed with the 4000 ppm SADH treatment in 1969 or 1970 (Table 16). Unrath et al. (47), also, reported that SADH concentrations up to 8000 ppm did not increase or decrease soluble solids.

SADH Residue

Residue samples were taken from each treated tree at harvest in 1969 and 1970. In 1969 there was a range of 3.2 to 3.8 ppm residue. However, there was no difference between nitrogen treatments (Table 17). Data in 1970 indicated that

TABLE 16.--Effect of Potassium and SADH on Soluble Solids at Three Weekly Periods in 1969 and Two in 1970.

	%Soluble Solids[1]				
	1969 Week			1970 Week	
	1	2	3	1	2
Potassium[2]					
K_0	11.3	11.6	12.4*	12.5	12.8*
K_1	11.7	11.7	12.7*	12.2	12.9*
	NS	NS	NS	NS	NS
SADH ppm					
0	11.5	11.8	12.4*	12.4	13.0*
4000	11.6	11.5	12.6*	12.3	12.8*
	NS	NS	NS	NS	NS

[1]Measured by hand refractometer.

[2]0, 2 pounds KCl per tree.

*Significant at 5% level.

NS Values not significantly different.

there was a three-fold increase in fruit residue when the same trees were sprayed two consecutive years. There was still no influence of nitrogen treatments on fruit residue.

Data from the potassium treatment indicated that there was no effect of potassium on the residue content of the fruit in either year (Table 17). All determinations suggested an

TABLE 17.--SADH Residue from Nitrogen and Potassium Treatments in 1969 and 1970.

	SADH Residue ppm[1]	
	1969	1970
Nitrogen[2]		
N_0	3.8	12.0**
N_1	3.2	10.8**
N_2	3.7	11.9**
	NS	NS
Potassium[3]		
K_0	3.6	11.1**
K_1	3.4	11.5**
	NS	NS

[1]Procedure as described by Ryugo (44).

[2]0, 3, 6 pounds NH_4NO_3 per tree in 1969; 0, 3, 9 pounds 1970.

[3]0, 2 pounds KCl per tree in 1969 and 1970.

**Significant at 1% level.

NS Values not significantly different.

increase in fruit residue after the second year of application which may be, in part, a carry over from the previous years application. However, residue values could be expected to vary from year to year depending upon climatic factors not studied. Many climatic factors, both at time of application

and during the growing season, may have influenced the residue values.

The typical SADH response was evident both in 1969 with an average residue of 4 ppm and in 1970 with a fruit residue average of 11.5 ppm.

No significant nitrogen x potassium interactions in relation to SADH residue were observed.

Processed Evaluations

Nitrogen, Potassium and SADH

In 1970 the processed fruit was stored for four months and then evaluated for drained weight, shear force, juice and fruit color.

Nitrogen treatments had no affect on drained weight of the processed cherries in either the No. 303 or No. 10 can. These treatments also had no influence on shear force (Table 18).

Potassium treatments had little or no effect on drained weight or shear force (Table 18). Potassium and nitrogen levels had no affect on fruit or juice color of the processed cherries (Table A4). In 1970 SADH treatment resulted in a decrease in drained weight of treated cherries in the No. 303 cans and an increase in drained weight in the No. 10 cans (Table 18). This discrepancy may be justified when the shear force data is examined. The force required to shear

TABLE 18.--Processed Cherry Evaluations from Nitrogen, Potassium and SADH Treatments in 1970.

	Drained Weight		Shear Force[3]		Color	Pits
	#303	#10	#303	#10	aL/bL	%
Nitrogen[1]						
N_0	10.62	114.80	37.56	24.47	1.50	7.1
N_1	10.60	113.39	34.00	23.00	1.52	7.0
N_2	10.62	115.27	38.81	25.66	1.53	7.1
	NS	NS	NS	NS	NS	NS
Potassium[2]						
K_0	10.59	114.30	36.96	23.42	1.57	7.0
K_1	10.65	114.67	36.63	25.33	1.47	7.1
	NS	NS	NS	NS	NS	NS
SADH ppm						
0	10.68	113.94	30.79	19.39	1.46	7.2
4000	10.55	115.04	42.79	29.35	1.57	6.9
	*	*	*	**	NS	*

[1]0, 3, 9 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

[3]Scale of 0 to 100 with 100 = 30 pounds force.

*Significant at 5% level.

**Significant at 1% level.

NS Values not significantly different.

the SADH treated fruit was much higher than untreated (Table 18). Therefore, the firmer fruit in the small No. 303 can may have retained its shape and drained more completely than the non-treated fruit, thus giving a lower drained weight than the control. The higher drained weight of the non-treated fruit could be due to the softer fruit with greater contact between the collapsed cherry surfaces. These surfaces may trap a greater percentage of liquid by adhesion than the firmer SADH treatment, thus higher drained weight. This factor may have been overcome in the larger sample of the No. 10 can and resulted in an increase in drained weight. The fruit in the No. 10 can was less firm than that in the small can. This may have been due to over cooking of the large units because of time required in heating and cooling.

SADH had no influence on color of the fruit as indicated by the Hunter aL/bL ratio (Table 18) or juice color (Table A4). Percent of pits was reduced by SADH treatment (Table 18).

Calcium Treatments

Drained weights for the three treatments; tap water, .2% calcium chloride and .2% calcium chloride plus ten minute cook at 140 F, were statistically lower than the distilled water treatment (Table 19). A partial explanation can be obtained for this decrease in drained weight by the shear force data (Table 19). Both of the .2% calcium chloride

treatments resulted in statistically firmer cherries than the distilled water treatment. The calcium chloride plus cook treatment gave firmer cherries than both the distilled and tap water treatments. This would suggest that these treatments may have made cell walls more rigid.

TABLE 19.--Processed Cherry Evaluations from Calcium Treatment in 1970.

Calcium Salts	Drained Weight	Shear Force	(a)[1]	aL/bL[1]
Distilled H_2O	10.79[a]	29.56[a]	18.81	1.67
Tap H_2O	10.59[b]	32.38[ab]	20.49	1.83
.2% Calcium Chloride	10.53[b]	40.94[bc]	17.78	1.60
.2% Calcium Chloride Cook 140 F 10 min.	10.56[b]	46.89[c]	18.58	1.59
	*	*	NS	NS

[1]Hunter color difference meter a an aL/bL values.

*Significant at 5% level.

NS Values not significantly different.

Values followed by unlike letters significant at 5% level.

LaBelle (37) also found that calcium chloride plus a precook resulted in a firmer product with lower drained weight. He suggested that when the cell wall was strengthened, it did not mean retention of fluids. As stated previously, the firmer cherry will retain its characteristic form and may drain more completely resulting in a lower drained weight.

The calcium treatments had no significant effect on fruit or juice color (Table 19, A5). These data suggest that firmness of sour cherries in a processed product is increased as calcium salts in the packing media are increased. No definite reason can be given for the lower drained weight obtained with the SADH or calcium chloride treatments.

Spectrographic Analysis of Leaf Samples

Leaf analysis from nitrogen treatments indicated no difference in manganese content due to nitrogen the first two years (1967, 1968) of treatment (Table 20). Data for 1969 and 1970 showed a highly significant increase in leaf manganese as nitrogen applications increased. From 1967 to 1970 manganese increased with the higher levels of nitrogen application. It is suggested that NH_4 from the applications of ammonium nitrate replaced manganese in the soil, thus manganese was more readily available to be absorbed by the roots.

Nitrogen applications had no significant effect on phosphorus, sodium, calcium, magnesium, iron, copper, boron, zinc and aluminum in the four years (1967-1970) that the treatments were maintained (Table A6, A7, A8, A9). The variations between years, could not be related to nitrogen treatments.

TABLE 20.--Leaf Manganese from Various Nitrogen Levels for 1967, 1968, 1969 and 1970.

	Manganese[1] ppm			
	1967	1968	1969	1970
Nitrogen[2]				
N_0	66	70	52[a]	58[a]
N_1	63	63	62[b]	68[b]
N_2	68	70	73[c]	85[c]
	NS	NS	*	*

[1]Appendix Tables 1A, 2A, 3A, 4A.

[2]0, 1.5, 3 pounds NH_4NO_3 per tree in 1967 and 1968; 0, 3, 6 pounds in 1969; 0, 3, 9 pounds in 1970.

*Significant at 5% level.

Values followed by unlike letters significant at 5% level.

NS Values not significantly different.

Potassium treatments had no detectable influence on uptake of phosphorus, sodium, calcium, magnesium, iron, copper, boron, zinc and aluminum in any one of the three years of treatment (Table A7, A8, A9).

When leaves from trees receiving SADH treatments for one year were analysed spectrographically for the above elements no obvious or statistical influence on the uptake of elements was observed (Table A8, A9). In 1970, however, after two years application at 4000 ppm, there was an increase in uptake of calcium and magnesium (Table 21).

TABLE 21.--Leaf Values from SADH Treated Plots for Calcium, and Magnesium in 1969 and 1970.

	Calcium %		Magnesium %	
	1969	1970	1969	1970
SADH ppm				
0	1.66	1.94	.39	.43
4000	1.69	2.04	.39	.50
	NS	*	NS	*

*Significant at 5% level.

NS Values not significantly different.

SADH Residue Survey

The rates of application for the thirty-four orchards were broken into five groups: (1) = 0-3 pounds SADH per acre, (2) = 4-6 pounds SADH per acre, (3) = 7-9 pounds SADH per acre, (4) = 10-12 pounds SADH per acre and (5) = 12 pounds or more SADH per acre. A linear response, significant at the 5% level, was found for SADH residue as pounds per acre increased (Table A10). A linear response to increasing concentration was reported, also, by Unrath, et al. (47).

A survey of SADH residues ranged from .96 to 18.7 ppm indicating that the FDA established residue value of 50 ppm had not been approached.

Related Responses

The enhancement of yield by increasing nitrogen applications associated with increased leaf nitrogen indicated that the levels of nitrogen were increasing the capacity of the tree to mature a full crop of cherries. This increase in yield was not accompanied by an increase in vigor as indicated by an increase in terminal growth. The lack of a significant increase in terminal growth could be, as stated earlier, improper sampling technique.

The terminal growth sampling technique could also explain why SADH appeared to be more effective on higher nitrogen rates with two years application at 4000 ppm than at lower nitrogen rates. Also, there were no measurements made to determine spur development and growth. It may be that high nitrogen resulted in more over all yearly growth than the lower levels. This was suggested by the increase in trunk circumference measurements. Thus the leaf nitrogen and trunk circumference would be better criteria for determining vigor than terminal growth. As reported SADH did not decrease trunk circumference measurements or leaf nitrogen values. However, it did decrease terminal growth by over 50% with two years application.

Reduced FRF coupled with an increase in firmness and color from SADH treatments indicate that SADH would permit harvesting sooner. Also, the reduced FRF resulted in less leaf removal and trunk damage during the shaking operation because less shaking was needed. The increased firmness

resulted in fruit that did not bruise as readily as untreated fruit; therefore, a superior processed pack that was indicated by the increase in shear force for treated fruit.

Color data in relation to leaf nitrogen, leaf potassium and SADH application is not clear. The data suggest that potassium increased color in one year and not in the other. SADH appeared to enhance color only to a given level. This could possibly be, as Chaplin (11) indicated, that SADH acts on the anthocyanin and sugar biosynthesis enzyme systems and increases color to a point where some other factor (possibly anatomical) has become the limiting one. Another possibility is the improvement in color by reducing the presence of poorly colored fruit.

Future Research

The results indicated by this thesis study suggest that the sour cherry responds to nitrogen, potassium and SADH in various ways. However, these data leave several points unanswered and raise additional questions.

It would appear that large increments in nitrogen applications or several years of smaller increments would be necessary to achieve a differential in leaf nitrogen. The same is true for potassium treatments. It is suggested that the relatively high rates of nitrogen and potassium applications be maintained so that the response of the sour cherry

can be determined more precisely. It might be pertinent to have a greater differential in leaf nitrogen and potassium so as to have near deficiency on one end and excess at the other.

SADH treatments need more testing to establish the terminal growth reduction in relation to leaf nitrogen. Perhaps, instead of spraying only at 4000 ppm each year a study could be initiated to evaluate the response of three to four years at 4000 ppm in comparison to 4000 the first, 2000 the second, and 1000 the third in combination with the fertilizer application rates.

Another area of research would deal with applications of SADH every year as compared to heavy crop years or every other year. Detailed work should be initiated or co-ordinated with growers to establish the most practical program for a given year. Also, the compatibility of SADH with pesticide and fungicides should be obtained. Data from one grower indicated no incompatability with sulfur. There had been some interest in the addition of an adjuvant to enhance the uptake of SADH or reduce the concentration needed for a desired effect. If concentrations of SADH could be reduced there would be a substantial savings in cost and possibly alter some other effects of SADH on growth and vigor.

Work also needs to be undertaken on processed sour cherry products to determine how the firmer SADH treated cherry is accepted. Some evaluations of the degree of firmness desired by consumers must be obtained.

SUMMARY

Field plots were initiated to establish nitrogen levels for sour cherry in the spring of 1967. The initial rates were 0, 1.5, and 3 pounds of NH_4NO_3 per tree spread around the periphery of each tree. These rates were increased each year until the level of 0, 3, and 9 pounds NH_4NO_3 were applied in 1970. In 1968 the plots receiving differential levels of nitrogen were split with 0 and 2 pounds of KCl per tree and maintained until 1970. The plots were further split with an SADH application of 4000 ppm, applied two weeks after full bloom in 1969 and 1970.

Nitrogen applications increased the yield of sour cherries by 25 pounds per tree in 1968 and 35 pounds per tree in 1969. Increased nitrogen had no significant effect on fruit color, did not increase the size of the cherries, nor did it result in a softer fruit. There was a significant increase in leaf nitrogen for high nitrogen application in both 1969 and 1970. Low application rates had a leaf nitrogen value of 2.65% in 1970 and high nitrogen a value of 2.83%.

Potassium treatments had no effect on yield, fruit removal force, size or firmness. Potassium did increase fruit

color in 1969, but the reverse was true in 1970. Potassium treatments resulted in a leaf potassium level of 1.13% for non-treated and 1.31% for trees receiving potassium in 1970.

SADH treatments increased fruit color and firmness early in the season in both 1969 and 1970. Fruit removal force was decreased by the SADH treatment in both years. The increased cherry firmness was maintained in a processed product in 1970, however, the increase in fruit color did not.

Terminal growth was decreased 25% by SADH treatment in 1969. In 1970 with two years application at 4000 ppm, there was a 55% decrease in terminal growth. However, trunk circumference measurements showed no decrease resulting from SADH treatment. There was a three-fold increase in SADH residue in fresh fruit with two years application. However, the average 11 ppm SADH residue in fruit for the two years application was far below the 50 ppm set by the FDA.

A firmer processed product was obtained with a .2% calcium chloride solution plus a precook at 140 F for ten minutes. SADH treatment also resulted in a firmer processed product.

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APPENDIX TABLES

TABLE A1.--Nitrogen x SADH Interaction in Relation to Yield. Pounds per Tree, 1969.

	SADH ppm	
	0	4000
Nitrogen[1]		
N_0	81	110
N_1	111	114
N_2	136	126

[1]0, 3, 6 pounds NH_4NO_3 per tree.

TABLE A2.--Nitrogen x SADH Interaction in Relation to Percent Leaf Nitrogen.

	1969 SADH,ppm			1970 SADH,ppm	
	0	4000		0	4000
Nitrogen[1]			Nitrogen[1]		
N_0	2.67	2.57	N_0	2.63	2.67
N_1	2.77	2.79	N_1	2.71	2.76
N_2	2.76	2.79	N_2	2.83	2.83

[1]0, 3, 6 pounds NH_4NO_3 per tree 1969; 0, 3, 9 pounds 1970.

TABLE A3.--Nitrogen x SADH Interaction in Relation to Fruit Color. (Absorbance 515 nm).

	1969 SADH,ppm			1970 SADH,ppm	
	0	4000		0	4000
Nitrogen[1]			Nitrogen[1]		
N_0	.54	.60	N_0	.79	.84
N_1	.57	.60	N_1	.80	.85
N_2	.59	.60	N_2	.86	.85

[1]0, 3, 6 pounds NH_4NO_3 per tree 1969; 0, 3, 9 pounds in 1970.

TABLE A4.--Processed Cherry Juice Color as Related to Treatments 1970.

	Color				
	Juice Color (515 nm)		Hunter* (#303 Can)		
	#303	#10	L	a	b
Nitrogen[1]					
N_0	.209	.211	26.8	19.3	13.6
N_1	.211	.207	27.1	19.1	13.3
N_2	.217	.219	26.7	18.2	12.0
	NS	NS	NS	NS	NS
Potassium[2]					
K_0	.215	.214	26.9	19.0	12.2
K_1	.209	.210	26.8	18.7	13.6
	NS	NS	NS	NS	NS
SADH ppm					
0	.211	.217	27.0	19.3	14.0
4000	.213	.208	27.0	18.5	11.9
	NS	NS	NS	NS	NS

[1]0, 3, 9 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

NS Values not significantly different.

*Hunter color difference meter L, a and b values.

TABLE A5.--The Effect of Added Calcium before Processing on Fruit and Juice Color 1970.

Treatments	Juice Color (515 nm)	Color L	Hunter* (Fruit) b
Distilled Water	.228	25.4	11.2
Tap Water	.223	26.1	11.6
.2% Calcium Chloride	.219	25.7	11.3
.2% Calcium Chloride Cook 10 min. at 140 F	.223	25.4	11.8
	NS	NS	NS

NS Values not significantly different.

*Hunter color difference meter L and b values.

TABLE A6.--Leaf Analysis[2] as Related to Nitrogen Applications 1967.

Nitrogen[1]	P	Na	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
N_0	.237	334	1.75	.45	66	181	25	24	18	219
N_1	.233	389	1.64	.42	63	180	23.0	22	16	200
N_2	.221	331	1.55	.41	68	182	23.0	23	18	166
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]0, 1.5, 3 pounds NH_4NO_3 per tree.

[2]P, Ca, Mg in %, others ppm.

NS Values not significantly different.

TABLE A7.--Leaf Analysis[3] as Related to Nitrogen and Potassium Applications 1968.

Nitrogen[1]	P	Na	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
N_0	.196	112	1.86	.34	70	113	20	29	11	123
N_1	.165	89	1.85	.28	63	107	16	27	11	122
N_2	.177	106	1.81	.25	70	115	17	27	12	129
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Potassium[2]	**P**	**Na**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**B**	**Zn**	**Al**
K_0	.178	98	1.82	.28	67.2	113	18	28	12	125
K_1	.181	107	1.85	.31	67.5	111	17	27	11	125
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]0, 1.5, 3 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

[3]P, Ca, Mg in %, others ppm.

NS Values not significantly different.

TABLE A8.--Leaf Analysis[3] as Related to Nitrogen, Potassium and SADH Applications 1969.

Nitrogen[1]	P	Na	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
N_0	.241	66	1.69	.43	52	70	19.3	30	19	197
N_1	.222	79	1.67	.38	62	75	18.1	30	18	202
N_2	.219	123	1.68	.36	73	72	18.0	30	20	200
	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Potassium[2]	**P**	**Na**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**B**	**Zn**	**Al**
K_0	.231	84	1.70	.39	62	74	18.8	30	20	200
K_1	.223	95	1.66	.39	63	70	18.1	30	19	199
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SADH ppm	**P**	**Na**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**B**	**Zn**	**Al**
0	.230	96	1.66	39	62	71	18.3	30	18	197
4000	.225	82	1.69	39	63	74	18.6	30	20	203
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]0, 3, 6 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

[3]P, Ca, Mg in %, others ppm.

NS Values not significantly different.

TABLE A9.--Leaf Analysis[3] as Related to Nitrogen, Potassium and SADH Applications 1970.

Nitrogen[1]	P	Na	Ca	Mg	Mn	Fe	Cu	B	Zn	Al
N_0	.187	104	2.07	.49	58	83	15	34	18	124
N_1	.178	108	1.94	.44	68	80	16	34	16	116
N_2	.179	123	1.95	.47	85	82	16	34	19	118
	NS	NS	NS	NS	*	NS	NS	NS	NS	NS
Potassium[2]	**P**	**Na**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**B**	**Zn**	**Al**
K_0	.182	106	1.95	.45	70	73	16	35	18	120
K_1	.180	116	2.03	.48	72	70	15	33	18	118
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SADH ppm	**P**	**NA**	**Ca**	**Mg**	**Mn**	**Fe**	**Cu**	**B**	**Zn**	**Al**
0	.182	112	1.94	.43	70	71	15	34	19	117
4000	.180	111	2.04	.50	72	72	16	34	17	121
	NS	NS	*	*	NS	NS	NS	NS	NS	NS

[1]0, 3, 9 pounds NH_4NO_3 per tree.

[2]0, 2 pounds KCl per tree.

[3]P, Ca, Mg in %, others ppm.

*Significant at 5% level.

NS Values not significantly different.

TABLE A10.--SADH Survey/Residue and Leaf Analysis 1970.

Rate[1]	SADH ppm	N %	K %	P %	Ca %	Mg %	Mn ppm	No. of Samples
1	2.16	2.66	1.34	.199	2.07	.58	72	2
2	4.31	2.67	1.17	.212	1.90	.62	71	14
3	6.25	2.68	1.18	.181	1.95	.61	60	7
4	6.94	2.46	1.11	.195	1.78	.49	72	8
5	11.39	2.80	1.09	.188	1.67	.56	65	3
	*	NS	NS	NS	NS	NS	NS	

*Significant at 5% level.

NS Values not significantly different.

[1]Rates: 1 = 0-3 pounds SADH per acre.
2 = 4-6 pounds SADH per acre.
3 = 7-10 pounds SADH per acre.
4 = 11-12 pounds SADH per acre.
5 = 12 pounds or more per acre.

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