Effects of Surround™ and Shadow™ spray materials on fruit sunburn and certain properties of mango *(Mangifera indica)* trees

by

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DECLARATION

As far as I am aware, this work is an original work by the auther and not the work of any other person or source.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract

The mango industry in South Africa lacks a commercial spray material that serves as a sunburn protectant on fruits. Despite the widespread use of labour-intensive polystyrene caps, high economic losses as a result of sunburn are experienced by growers. Two spray materials Surround™ and Shadow™, were tested as sunburn protectants on mangoes under tropical climatic conditions. The spray materials were applied fortnightly to fruits and trees from golf-ball size to harvest. Relative to controls, both Shadow and commercial standard polystyrene caps for individual fruits reduced sunburn damage on fruits by 96%, whereas Surround reduced sunburn by 51%. The spray materials had no negative effects on fruit yield, photosynthetically active radiation, nor fruit colour development. However, yields under cap treatment were lower due to abnormally higher fruit drop. Also, Surround and Shadow suppressed feeding by insects such as thrips and predators for mango scale, thus creating favourable conditions for the build up of mango scales on leaves. Mango trees defoliated and did not flower during the normal flowering period, and leaves infected with mango scale turned yellow and died. Major physiological disorders and internal breakdown of stored fruits were not observed. Also, the two materials had no detrimental effects on

flavour of mango fruits. The spray material Shadow has potential for use as a sunburn protectant because it does not wash off the fruits when it rains.

Chapter 1
Introduction

Mango (*Mangifera indica L.*) is one of the major economic tropical fruit crops grown in the Northern Province and the infection Province of the Republic of South Africa. Total fruit production during the 1997/1998 season was 57 891 tons, with a total value of R95.8 million (infestation, Conradie and Le Lagadec, 1998). The income per kg from the export fruit is higher than that for local markets. Due to stringent overseas grading standards, only 16% of the 1998 crop was exported, whereas the remaining crop was sold to either local fresh markets (30.2%), atchar processors (34.4%) or dried fruit markets (4.3%) (Köhne *et al.*, 1998).

A total of 3 286 403 mango trees, covering approximately 7 748 ha, are found mainly in the commercial farming sector. However, with the relaxation of controlled marketing, a large number of smallholder farmers in the Northern Province and Mpumalanga Province have since started to establish mango orchards on their holdings for commercial production.

Beside culls resulting from pest, disease and wind damage, high economic fruit losses due to sunburn damage are experienced by mango growers in the hot tropical Lowveld region of the Northern Province (SAMGA, 1999). Sunburn, commonly referred to as sun scald, is described as a physiological disorder that causes a necrotic lesion on the fruit skin and a browning of the flesh underneath (Warner, 1997). South African growers lose as much as 10% of their potential exportable mango crop due to sunburn, which is equivalent to monetary losses of R4 million. The mango industry is presently earning R40 million from exports, with a potential of expanding to R500 million in the next 5 years, since most of the commercial orchards are still young (Köhne *et al.,* 1998).

The tropical Lowveld region of the Northern Province is characterized by high temperatures in summer, with some areas experiencing ambient day temperatures as high as 40°C (Köhne *et al.*, 1998). The region is suitable for the production of mangoes except for its high incidence of insect pests, diseases and sunburn problems. Without the proper management of either problem in the region, production of mangoes would not be economical.

Around the world some fruit growers manage sunburn using shade-cloth, reflective substances, fruit bags, and even overhead sprinklers (Andrews, 1997). Shade-cloth reduces direct sunlight through interception, reflection and dispersal, thus lowering ambient temperatures. Reflective substances increase the reflection of direct sunlight, whereas fruit bagging prevents direct sunlight contact on fruits. Overhead irrigation reduces fruit temperature through evaporative cooling. The disadvantages of these methods were reported by various workers (Andrews, 1997; Bergh, Franken, Van Zyl, Kloppers and Dempers, 1980; Warner, 1997).

In the Lowveld, sunburn caps have been widely used by mango growers to protect fruits from sunburn damage. However, fitting of caps on individual fruits is labour intensive, and with current employer-unfriendly labour laws in South Africa, evaluation of alternative sunburn control measures is imperative. Surround™ and Shadow™ are being evaluated es sunburn control materials on fruit crops in various fruit-producing areas of the Republic of South Africa. The objective of this study was seven-fold: to evaluate effects of Surround™ and Shadow™ spray materials on (1) sunburn on mango fruits, (2) fruit yield, (3) carbon assimilation, (4) feeding by selected insect pests, (5) infection by selected pathogens, (6) incidence of certain post-harvest physiological disorders, and (7) removal of spray material residues on fruits in the packhouse.

Chapter 2
Literature Review

2.1 Introduction

Litz (1997) reported that the mango (*Mangifera indica L.*) can withstand a wide range of subtropical climates, which is evident from the fact that mangoes are grown successfully in Mediterranean-like climates and in hot-humid tropical and semi-arid subtropical regions. Most of the mango-producing areas in the Lowveld experience high maximum temperatures during December and January months, and fruits on limbs facing the north and northwest inevitably become sunburnt. Köhne *et al.* (1998) reported that summer daytime ambient temperatures of the major mango-producing areas vary from 28°C to 40°C, whereas in winter they vary from 18°C to 30°C. Night temperatures vary from 15°C to 25°C in summer, and 5°C to 15°C in winter. The high day temperatures invariably result in sunburn of exposed fruits. Exposed fruits on trees can be much warmer than air temperature, sometimes as much as 12°C and 14°C higher (Van den Ende, 1999).

2.2 Losses due to sunburn

Sunburn induces large economic losses on pomological and certain olericultural crops. Annually, mango growers in South Africa lose as much as 10% of their potential exportable crop due to sunburn, which is equivalent to a loss of R4 million. The mango industry is presently earning R40 million from exports, with the potential of growing up to R500 million in the next 5 years, since most orchards are still young or are being planned (Köhne *et al.*, 1998; SAMGA, 1999). Warner (1997) reported that as much as R700 million a year may be lost to Washington State's apple growers because of sunburn damage.

Evans, Kroeger and Mahan (1995) reported that sunburn in 1991 on American apples was the major culling factor, contributing 34% of the total cullage when compared with the 6% loss due to scab. Also, apples in New Zealand suffer greatly from sunburn damage. During the 1998/1999 season, sunburn fruit culls averaged 15% in some New Zealand cultivars (Brooks, 2000). The 15% culls were as recorded at the packhouse, suggesting that the figure would be much higher when fruit culls left in the orchards were recorded. Brooks (2000) further reported that low sun and cloudy conditions in late December and January increased fruit sensitivity to sunburn as conditions are sunnier prior to harvest.

Andrews (1997) observed that growers in Washington State who bagged Fuji apples on trees to improve fruit finish, sometimes unintentionally cook apple fruits inside the bags. Andrews (1997) reported that the skin on the sun-exposed side of an apple fruit can be as much as 11°C to 14°C higher than the ambient temperature. The skin temperature on the exposed side of a bagged apple is 2°C higher than that of the non-bagged apples. The time and duration of direct exposure to the sun and the amount of air circulation are the main factors affecting fruit temperatures. Fruit size, wind direction and fruit transpiration are of lesser importance (Van den Ende, 1999). The market requirement for enhanced colour in apple fruits increases under sunnier conditions, where sunburn is likely to become a more serious management problem.

2.3 Effects of environmental factors on sunburn

Movement of the sun in the orchard has serious economic implications on fruit quality. Bergh *et al.* (1980) demonstrated that in South Africa sunburn on apples could be reduced significantly if the northern to north-western sides of the trees were protected by inducing more growth on those sides. Conradie (2000) observed that most mango fruit on the north western side of a tree canopy had higher sunburn rates when compared with the fruit on the eastern side of the canopy. Van den Ende (1999) also observed that sunburn on apple fruits in the Southern Hemisphere was always worse on the north and northwest sides of the trees. Fruit damage occurs during the period from 12h30 to 15h15 on days when the air temperature rises above 30°C. Direct sun rays reached fruits on the northern to north-western sides and the provision of leafy shoots on those parts of the trees by judicious pruning and fruit thinning prevented fruits on the remaining parts of the trees from being exposed to the sun during critical periods (Bergh *et al.*, 1980).

Roe and Morudu (1999) found that Hass avocado fruits borne from determinate flowers were sunburnt due to lack of foliage protecting them against direct sunlight. Bergh *et al.* (1980) observed that apple fruits which developed in the shade during the early part of the season and were later exposed to the sun, were more susceptible to sunburn than those which had been exposed to the sun from the beginning of the season. Also, Bergh *et al.* (1980) reported that apple fruits near the soil surface had much higher temperatures on hot days than fruits on the higher branches due to the higher soil temperatures near the soil surface, where less air circulation occurred. Bergh *et al.* (1980) reported that air circulation in the orchard was of utmost importance for expelling warm air surrounding fruits. In the Grabouw area, they found that on exceptionally hot days, there was only a slight breeze from the south-east. Thus, dense windbreaks on the south-eastern sides of orchards would retard air movements to a great extent and, therefore, had adverse effects on lowering air temperatures in the orchards. They demonstrated that fruit temperatures were influenced mainly by intensity of radiation and air circulation. Sunburn on fruits is caused by an interaction of high fruit temperatures and high light intensities. Amounts of air circulation around trees and tree water status are other factors that influence fruit sunburn (Van den Ende, 1999).

2.4 Management of sunburn

Sunburn problems are not easily controlled, but can be alleviated by using white wash (Litz, 1997). However, whitewash comes off the fruit when it rains. Commercial polystyrene caps are widely used in management of mango fruit sunburn. Le Lagadec (1999) reported that 'Kent' mango fruit fitted with sunburn caps were not sunburnt, but tended to have lower percentage fruit retention than those without caps.

Certain growers use evaporative cooling to reduce sunburn damage. Evaporation on fruits releases latent heat, which has a cooling effect. However, long-term overhead irrigation for cooling invariably results in leaching out of nitrogen and other nutrients from the rhizosphere (Andrews, 1997; Warner, 1997) and potentially higher disease levels. Andrews (1997) reported that reflective cloths do not attract light, thus if light does not strike the reflective material, it will not enhance fruit colour in the lower canopy.

Certain apple growers in the United States of America and in Europe reduce sunburn damage by using overhead shading materials and water sprinkling (Andrews, 1997). Growers using hail netting have had more reduction in sunburn, but the initial outlay cost is limiting. In Central Otago, where overhead irrigation is used to combat frost damage in early spring, orchardists use their irrigation system for hydro-cooling to reduce apple fruit temperature and sunburn (Brooks, 2000). Also, growers found that water application treatments to the whole canopy in mid-season cultivars reduced mean fruit skin temperature by up to 8°C. Some cultivars were more susceptible to sunburn than others, and the possible hypotheses relate to temperature, UV radiation, transpiration rates (the evaporative cooling capacity of the fruit), skin morphology and skin pigments (Warner, 1997). Andrews (1997) proposed that an understanding of genetic differences in fruits may help explain why some some cultivars are more susceptible to sunburn than others.

Evans (1998) reported that avoiding excessively high leaf and fruit temperatures during the hottest part of the day can greatly reduce the incidence of sunburn. Growers who have used evaporative cooling prior to sunset and sometimes around sunrise, have improved colour development before harvest on red apples especially on early varieties. Stevens (1998) reported that the major concern with overtree irrigation or cooling is the deposition of a precipitate on leaves and fruit as the irrigation water evaporates.

Van den Ende (1999) reported that annual shoot growth in apple should at least be 20 to 30 cm to enable most fruits to enjoy filtered light rather than excessive amounts of direct sunlight. Branches bearing fruit should not be allowed to bend over and expose fruits that were previously in the shade (Van den Ende, 1999; Bergh *et al.*, 1980). Pruning of branches is not recommended during the fruiting period as the removal of such branches will expose some of the remaining fruits which were located in the shade and might possibly also alter the position of the remaining branches, thereby, exposing fruits which were in the shade. Also, Van den Ende (1999) reported that fruits burn less if the trees were irrigated regularly, thus, maintaining the tree water status and the ability of the tree to regulate its temperature by transpirational water loss.

2.5 Spray materials

Sibbett *et al.* (1992) reported that sunburn protection on Granny Smith apples on the tree could be obtained by up to four applications of a whitening agent referred to as Sunguard. In 1999/2000 Surround™, another whitewashing agent, was evaluated on apples and pears in the Western Cape. The material reduced sunburn and it had no negative effects on yield (Le Grange, Wand and Theron, 2000). Also, Surround reduced certain insect population densities.

Since the 1960s, there has been little interest in inert minerals as insecticides because of the availability of cheap and effective synthetic chemicals. Many synthetic chemicals are currently suspended due to their various health and environmental hazards. Also, increasing numbers of consumers demand food or products with less or no inputs of synthetic agro-chemicals (Glenn *et al.*, 1999). Trees and plants along dirt roads that become covered by road-dust have been known to be susceptible to phytophagous mite and scale outbreaks because dust deters their natural enemies (Debach, 1979). Foliar application of kaolin was shown to be phytotoxic by damaging cuticles of leaves and increasing water loss (Eveling, 1972; Eveling and Eisa, 1976). Recent work on mineral particles as pesticides has been limited to formulations containing particles impregnated with synthetic pesticidal compounds (Kirkpatrick and Gillenwater, 1981; Margulies, Stern, Rubin and Ruzo, 1998).

Mineral-based whitewashes have been examined for the prevention of insect-vectored transmission of viral plant diseases. Marco (1986) demonstrated that weekly sprays with reflective whitewash materials, referred to as Loven and Yalbin reduced potato leaf roll virus (PLRV) and potato virus Y (PVY) incidence in potato crops by 30% and 40%, respectively. Lowery, Sears and Harmer (1990) also showed that weekly applications of whitewash provided a reduction in aphid numbers and turnip mosaic virus infection. Marco (1986) noted that the reduced landing of aphids on whitewash-treated pepper plants was probably due to their increased reflectivity on leaves. The effect of these materials on aphid landing probably depend on their reflective properties, ambient climatic conditions, and the specific vector species involved. Marco (1986) reported that some aphid species, like *Aphis citricola*, were repelled to a greater degree than others, whereas *A. gossypii* was attracted to whitewash-sprayed pepper plots. Similar results were obtained with kaolin sprays (Bar-Joseph and Fraenkel, 1983) and with reflective mulch (Smith and Webb, 1969). The selective repellence indicates that, for practical use of whitewash spray, one should take into account not only the climatic conditions but also the vector species involved in the crop and the area. White reflective substances repelled certain aphids by affecting their host-finding and settling responses (Kennedy, Booth and Kershaw, 1961; Kring, 1962).

Whitewash formulations vary, and are generally composed of kaolinite, bentonite, and attapulgite with the addition of spreading and sticking agents that are designed to enhance the adsorption of whitewash on plant foliage or soil (Bar-Joseph and Fraenkel, 1983; Marco, 1986; 1993; Nawrocka, Eckenrode, Uyemoto and Young, 1975). Marco (1986) found that whitewash technology had limited success in repelling aphids and leafhoppers in pepper.

Whitewashes increased leaf reflectance (Cohen and Marco, 1979; Marco, 1986; Mor, 1989), thereby reducing its temperature, which could explain the observed increased yields under supra-optimal temperature conditions and decreased yields in relatively low temperatures when whitewash was used. Baradas, Blad and Rosenberg (1976) reported increased leaf temperature of whitened soyabean leaves. Reducing radiation absorption decreased CO_2 uptake by indirectly reducing stomatal opening or by decreasing leaf temperature to a sub-optimal level (Basnizki and Evenari, 1975). Duggar and Cooley (1914) reported no increase in transpiration rates of tomato leaves treated with suspensions of calcium carbonate, aluminium hydroxide or Bancroft clay. The application of Bancroft clay increased transpiration of tomato leaves (Horsfall and Harrison, 1939).

Surround™ is a trade name for kaolin. Kaolin is a white, nonporous, nonswelling, non-abrasive fine-grained platey aluminosilicate mineral ($Al_4Si_4O_{10}(OH)_8$). Surround easily disperses in water and is chemically inert over a wide pH range. Coated grade kaolin is more than 90% pure and has a brightness index of greater than 85%. Mined kaolin has traces of two metals, namely, Fe_2O_3 and TiO_2. The former must be removed to obtain a brightness index greater than 85%, which is normally required for certain industrial applications (Harben, 1995).

2.6 Effects of spray materials on pests and diseases

Glenn, Puterka, Vanderzwet, Byers and Feldhake (1999) reported that agricultural research on dusts had been neglected because it had been implicated in reducing plant productivity and inducing arthropod pest outbreaks on plants. Mineral particles originating from quarrying, open-pit mining and road traffic were also reported to decrease plant productivity and increased aphid pests and fungal infections (Farmer,1993).

From the1920s to the 1960s, considerable research was conducted on mineral particles to identify those that had insecticidal properties and to determine the mechanism of insecticidal action (Glenn *et al.*, 1999). Extensive screening of a wide range of minerals on four species of granary weevil larvae (Alexander, Kitchener and Briscoe, 1944), on adult grain and four beetles (David and Gardiner, 1950), and on termites *(Kaolitermes minor* Hagen) by Ebeling and Wagner (1959), showed that hard nonsorptive particles (e.g. diamond and quartz) or soft porous sorptive particles (silica oxide and aluminum oxide) were the most effective insect killing agents. Effectiveness increased as particle size decreased to an ideal size of 1-2μm because of the improved adherence to the insect cuticle. The primary mechanism of action involved the partial removal of the insect's outer cuticle (epicuticle) through abrasion by nonsorptive particles (Kalmus, 1944; Wigglesworth, 1944; David and Gardiner, 1950) or structural disruption of the epicuticle by adsorption of epicuticular lipids to sorptive particles (Alexander *et al.*,1944; Hunt, 1947; Ebeling and Wagner, 1959). Both mechanisms induced rapid water loss from the insect's body and caused death by dessication. Kitchener *et al.* (1943) also demonstrated that certain chemically inert dusts kill insects by causing dessication.

Glenn *et al.* (1999) reported that research on the use of inert mineral particles as control agents for foliar bacterial and fungal diseases had been lacking. Most research on foliar diseases had focussed on the use of mineral compounds, such as sodium carbonate, which is caustic and modifies the pH of the plant surfaces under moist conditions. Thus, the germination and growth of fungal diseases may be prevented (Olivier, Halseth, Mizubuti and Loria, 1998). Marco, Ziv and Cohen (1994) reported that in field experiments with squash Loven and Yalbin reduced disease severity on the upper side of old leaves by 53% and 59%, respectively, and on young leaves by 12% and 18%, respectively. In a controlled environment, Marco *et al.* (1994) found that Loven and Yalbin reduced disease severity by 38% and 56%, respectively, and that the addition of 1% Dabak (sticker) increased whitewash efficacy, thus reducing disease severity in both treatments by 22%. Marco *et al.* (1994) demonstrated that whitewash reduced the incidence and severity of powdery mildew in squash, and also speculated that whitewash might protect plants against viral and other fungal diseases. The results of their study indicated that the protective efficiency of whitewash against powdery mildew in squash was comparable to that of an antitranspirant, but that both were less efficient than a fungicide. Whitewashes, especially clays, are relatively inexpensive, ecologically sound for organic agriculture and appear to have a beneficial effect on plants which become taller and greener, as manifested by a higher chlorophyll content of the older leaves. It was also known for the first time that inert clays consisting mainly of kaolin appear to have similar effect on powdery mildew suppression in squash. Foliar applications of potassium silicate to cucumber, muskmelon, and zucchini squash reduce the number of colonies of powdery mildew pathogens (Menzies, Bowen, Ehret and Glass, 1992; Samuels, Glass, Ehret and Menzies, 1991a). Samuels, Glass, Ehret and Menzies (1991b) found that the effect of silicates (Si) in decreasing the severity of powdery mildew on cucumber leaves was lost within 24 hours of removing Si from the nutrient solutions. Whitewash sprays reduced the incidence of potato virus Y (PVY) and cucumber mosaic virus (CMV) in pepper (Marco, 1993). Also, Lobenstein and Raccah (1980) reported that insecticides provided no protection against nonpersistently transmitted viruses in pepper.

2.7 Effects of spray materials on yield, transpiration rate and leaf temperature

Whitening the canopy of the cotton crop with kaolin increased yield in a 1975 experiment by 12.6% (Moreshet, Cohen and Fuchs, 1979). In 1976, the effect of kaolin on yield was not significant, although the kaolin spray produced a clear effect on flowering, where percentage fruit set decreased rapidly with time in both control and treated plots. Moreshet *et al.* (1979) demonstrated that in sorghum and cotton, the plant height, dry matter and LAI were significantly modified by kaolin spray. Andrews (1997) reported that besides lowering fruit temperature, in the long term, shade cloths resulted in a decline of apple yields due to the reduced amount of intercepted light in the orchard. Lowery *et al.* (1990) reported an increase in yield of rutabagas treated with whitewash. Marco (1986) showed that whitewash sprays decreased the total yield of potato tubers, which was in disagreement with previous reports which showed that Yalbin increased yields of sorghum (Stanhill, Moreshet and Fuchs, 1976) and artichoke (Basnizki and Evenari, 1975).

Moreshet *et al.* (1979) found that the response of stomata to kaolin spray was different from that reported by Eveling (1969). Eveling (1969) observed that spraying stockalite clay on leaves increased the transpiration rate, which implied that the materials had fewer effects on stomatal aperture. Also, Eveling (1972) found that eleven out of twenty leaflets of runner beans sprayed with stockalite had yellow areas below the deposits, and six sprayed with copper oxychloride showed slight damage three weeks after spraying. Eveling (1969) reported that copper oxychloride deposits caused less damage to leaves than an 'inert' dust during a three week period, and a slowing of transpiration rates on leaves lessened damage by either copper oxychloride or dust deposits. Water loss, not cell poisoning, appear to be a major cause of damage to plants treated with 'inert' spray materials. Apparently, the damage was dependant on the physical effects of the dry particles on tissues (Eveling, 1972). Increased transpiration caused by mechanical effects of a fungicide reduced potato yield when plants were sprayed during hot dry weather in the absence of late blight (Eveling, 1972).

Kaolin decreased stomatal conductance by permanently obstructing stomatal apertures (Moreshet *et al.*, 1979). Also, kaolin reduced CO_2 uptake. Reflective whitewash was reported in California and Israel to prevent sunburn on stems and trunks of tomatoes and peaches, respectively (Lavee, Assa and Samish, 1964). Basnizki and Evenari (1975) observed that the larger the leaf area, the greater the temperature difference between both sides of the treated leaf. However, kaolin-treated leaves of the same size were always cooler than the untreated controls. Basnizki and Evenari (1975) proposed that lowering the leaf temperature increased reflectance of the leaf, especially the reflection of Infra-red (IR) waves which are non-photosynthetic, but increase leaf temperature. Also, the two workers showed that the abaxial surface of treated leaves was always warmer than the adaxial surface. Basnizki and Evenari

(1975) showed that the relative diffusion resistance of treated adaxial surfaces of large and medium sized leaves was lower than that of the untreated leaves. Temperatures of treated leaves were lower than those of controls. However, treated leaves had a shorter transition time.

2.8 Effects of spray materials on fruit quality

Van den Ende (1999) reported that after storage flesh breakdown could be observed from fruits that were sunburnt. Also, the skin was susceptible to cold damage. Brooks (2000) reported that in apples there had been a concern over ripeness and colour retardation. The fruits on the trial trees, when rubbed free of the products, were greener than the fruit on the control trees on the 'Braeburn' and 'Fuji' trees. Both cultivars require selective background or groundcolour , and a blush colour to determine picking; when colour is not visible it presents a problem. Brooks (2000) reported that removing whitewash material from the apples after harvest was a difficult exercise.

2.9 Motivation of the study

Mango constitutes about 2-5% of the total agricultural produce exported from the Northern Province by commercial and emerging small scale farmers. The exportable percentage could be increased if products designed to protect mango fruit against sunburn were effective. The Venda Farmers Association reported that many emerging small scale farmers are becoming mango growers because of the support from the South African Mango Grower's

Association (SAMGA) and the Outreach Programme spearheaded by Merensky Technological Services (MTS) (Mabila, M. E., personal communication). Emerging small scale farmers use established commercial farmers and extension officers as their source of information on how to overcome the problems that they experience on their farms, including sunburn and insect control. Thus, it is imperative to investigate the effectivity of new spray material that can be used by mango growers as sunburn protectant, as well as to determine and quantify their suppression on pests and diseases, as well as physiological disorders.

CHAPTER 3
Control of Sunburn on Mango Fruits by Using Spray Materials and Caps

3.1 Introduction

Despite the use of caps and 'Reflecto' on mango fruits for sunburn control in mango-producing areas of South Africa, high economic losses are still experienced by growers. Mango growers are losing about 10% of their potential exportable crop due to sunburn (Conradie, 2000). Presently, Surround™, a product made from kaolin, by the Engelhard Corporation, USA, is being evaluated in the Western Cape on apples against sunburn, and it showed that it has certain merits and demerits (Le Grange *et al.*, 2000). Shadow™, which is an Israeli product, has successfully reduced sunburn on apples in Israel. However, effects of Surround and Shadow as spray materials against sunburn on mango fruit have not been evaluated. The objective of this study is to evaluate the effects of Surround and Shadow spray materials on: (1) mango fruit sunburn, (2) fruit yield, (3) carbon assimilation, (4) feeding by selected insect pests, (5) infection by selected pathogens, (6) post harvest physiological disorders, and (7) self residues on fruits in the packhouse.

3.2 Materials and methods

The trial was carried out on the mango cultivar 'Sensation' from September 1999 to February 2000 at Constantia Estate (23° 40' S; 30° 40' E; 457 m above sea level), which is characterized by a hot and dry climate. The experiment was carried out on 8-year old 'Sensation' grafted on 'Sabre' seedling rootstock, planted at 7 m x 1.5 m spacing. Water was applied to the roots of mango trees through a drip irrigation system monitored by means of tensiometers. Fertigation was used to apply fertilizers to the roots of the trees. Annual leaf analysis determines the amount of fertilizer to be applied per annum per tree. *Casuarina cunninghamiana* (Beefwood) trees served as windbreaks to protect mango trees against breaking of branches, fruit blemishes and spreading of bacterial black spot spores by wind.

Treatments applied were (1) untreated control, (2) standard sunburn airophene caps, (3) Surround at full rate (Surround full), (4) Surround at half rate (Surround half), and (5) Shadow. Treatments were arranged in a complete randomized block design with four replicates. Each plot comprised 15 trees, with three rows of mango trees between the treatments serving as buffer rows to prevent contamination by the drifting of spray materials. The products were separately applied as a full cover spray to trees using a mist blower mounted on a tractor. The capacitor of the mistblower was set to 15 bars producing *3 143 ℓ* H_2O *per hectare or 3.3 ℓ* H_2O *per tree*. The treatments were initiated when fruits were at golf-ball size and then fortnightly for a total of 9 applications until harvest. Airophene caps were fitted on fruits situated on the north-western sides of the tree canopies only.

The study comprised pre-harvest and post-harvest evaluations. Data were subjected to analysis of variance (ANOVA) with SAS software (SAS Institute Inc., Cary, NC, USA), followed by mean separation with Duncan's multiple-range test when F values were significant at $P \leq 0.05$.

3.2.1 Pre-harvest evaluation of spray materials

3.2.1.1 Sunburn ratings

Ten randomly selected fruits per tree within each treatment were rated for sunburn damage in January after 8 applications of the spray materials. The rating scale used to quantify severity of sunburn damage was 0= no sunburn damage, 1= slight damage, 2= mild sunburn damage, and 3= severe sunburn damage.

3.2.1.2 Photosynthesis measurements

Five trees per replication were randomly selected and evaluated for photosynthesis under control, Shadow and Surround in February 2000 after 9 applications of the spray materials. Photosynthesis measurements were carried out using an Infra-red Gas Analyzer (CIRAS 1, PP Systems, UK). Measurements were taken from individual leaves by clipping onto a leaf with leaf cuvettes of the Infra-red Gas Analyzer, which measures photosynthetically active radiation (PAR, 400-700 nm), internal carbon dioxide (CO_2), leaf temperature, vapor pressure deficit, stomatal conductance (E) and sap flow.

3.2.1.3 Insect activities

Populations of thrips, mango scales and mango weevils were evaluated during fruit development. Ten randomly selected fruits and leaves per tree within each treatment were rated repeatedly for thrips and scale damage, respectively. Thrip populations were visually counted on small fruits a week after the application of the first and second sprays of the spray materials. Mango scale was monitored once a month after two sprays of the spray materials.

3.2.2 Post harvest evaluation of spray materials

At harvest, after the 9 applications of the spray materials, fruit samples of 16 cartons (4 kg/carton) per treatment were collected, subjected to commercial packhouse procedures (i.e water, wet brushes, hot water at 50°C, fungicide solution, drying brushes and wax), and immediately stored at 11°C for 28 days.

3.2.2.1 Sunburn damage

All experimental fruits were evaluated for sunburn. Sunburn evaluation was done using the rating scale as described previously in 3.2.1.1.

3.2.2.2 Fruit yield

Yield per tree (kg) was measured using a Mettler,Toledo model, scale. Total fruit yield per treatment was extrapolated to tons/ha.

3.2.2.3 Insect damage

Insect damage was determined visually before fruits were cut open in the laboratory. Fruits were then rated for damage caused by thrip, mango scale and mango weevil on a 0-3 rating scale.

3.2.2.4 Fruit diseases

Anthracnose and soft brown rot, after 28 days in cold storage, were visually evaluated when fruits were ripe.

3.2.2.5 Physiological disorders

Physiological disorders of fruits were evaluated at the Merensky Technological Services (MTS) fruit evaluation laboratory. The following physiological disorders were evaluated:

(i) Lenticel damage manifested as external marks on fruit induced by various unknown factors was evaluated through visual inspection.

(ii) External colour of a mango fruit was evaluated visually against the background color of that fruit using colour charts.

(iii) Internal colour development, which indicates the degree of fruit maturity at the time of harvest, was evaluated using colour charts.

(iv) Internal breakdown, which is characterized by spongy tissues, cavities of the mesocarp, was evaluated through visual inspection.

(v) Jelly seed, where flesh around the seed of fruit becomes soft like a gel and browning occurs was visually inspected.

(vi) Total soluble solids, which is the sugar content of the fruit was evaluated by using a hand model refractometer measuring in Brix.

(vii) Taste of fruit was evaluated by eating flesh of each fruit to be evaluated, to find whether treatments applied influenced the taste of the fruit negatively or not.

3.2.2.6 Residue on fruits

When fruits entered the packingline, normal packhouse procedures were applied to determine whether the sprayed materials came off the fruit without leaving residues or marks on fruit. Fruits were received in the reception bath, washed with water using wet brushes, sorted for mechanical and insect damage, placed into hot water at 50°C for 5 minutes, passing through a fungicide solution, into a drying tunnel with drying brushes, and finally into a waxing station. Fruits were collected after the waxing station and evaluated visually for shininess and residues of spray materials.

3.2.2.7 Fruit firmness

After harvest, the starch in the fruit is converted into simple sugars making the fruit to soften until eat-ripe stage is reached (ripening of fruit follows this sequence: hard, break and keep on softening until eat-ripe stage). Fruit firmness can either be measured outside or inside of the fruit using a densimeter or penetrometer. Horticultural industry is using these instruments to measure firmness to ensure that good quality fruit reaches distant markets while still hard.

3.3 Results

3.3.1 Pre-harvest evaluation of spray materials

3.3.1.1 Effects on sunburn

Effects of various sunburn control materials in controlling sunburn damage on mango fruits are summarized in Figure 3-1. In the untreated control trees, 46% of fruits were free from sunburn damage. Both caps and Shadow had 90% fruits that were free from sunburn damage. Surround full and half rates had 48% and 50% fruits that were free from sunburn damage, respectively. Compared with the controls, caps and Shadow each reduced sunburn by 96%, whereas Surround full and half rates reduced sunburn by 4% and 9%, respectively.

3.3.1.2 Effects on insects

Effects of various sunburn control materials on thrip (*Scirtothrips aurantii*) populations feeding on mango fruit when monitored at two weekly (8 days after spraying) intervals after the application of spray materials are shown in Table 3-1. Surround and Shadow suppressed populations of thrips at both sampling times, whereas the cap treatment had high thrip populations at both sampling times.

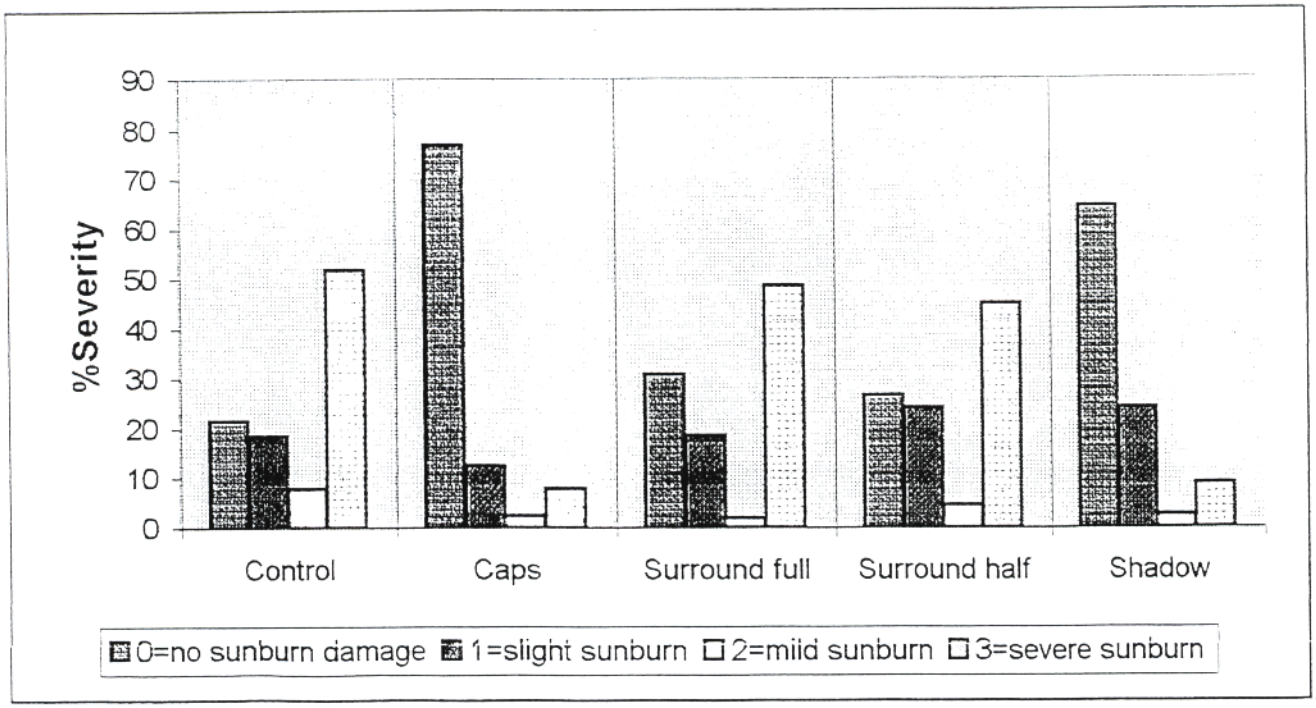


Figure 3-1. Effects of various sunburn control materials in controlling sunburn damage on mango fruit

TABLE 3-1. Effects of various sunburn control materials on average thrip (*Scirtothrips aurantii*) populations feeding on mango fruit when monitored at 8 days after the application of spray materials

Treatment	1st scouting (week 41)	2nd scouting (week 43)
Control	150.50 b[y]	56.50 a
Caps	219.00 a	63.75 a
Surround full	31.75 c	1.75 b
Surround half	28.25 c	8.50 b
Shadow	22.25 c	11.25 b

[y] Treatment means in each column followed by the same letter were not different ($P \leq 0.05$) according to least significant difference test.

Effects of various sunburn control materials on the occurrence of mango scale on mango leaves are shown in Table 3-2. According to the first scouting (8 days after spraying) all treatments resulted in significantly fewer mango scales on leaves of treated trees. There were no significant difference between sunburn control treatments. Based on the observations of the second scouting (8 days after treatment), Surround and Shadow resulted in scale counts significantly lower than on control trees or those treated with caps.

TABLE 3-2. Effects of various sunburn control materials on the occurrence of mango scale (*Aulacaspis tubercularis*) on mango leaves

Treatment	1st scouting	2nd scouting
Control	67.00a [y]	71.50 a
Caps	39.25 b	72.25 a
Surround full	23.25 bc	28.00 b
Surround half	38.75 b	35.00 b
Shadow	11.75 c	13.75 b

[y]Treatment means in each column followed by the same letter were not different ($P \leq 0.05$) according to least significant difference test.

3.3.1.3 Effects on photosynthesis

Effects of spray materials on photosynthetically active radiation (PAR), internal carbon dioxide (CO_2 int), leaf temperature (leaf T °C) and vapour pressure deficit (VPD dif) of mango trees are summarized in Table 3-3. Shadow-treated mango trees had significantly higher PAR than Surround-treated trees, but did not differ significantly from the control. The internal CO_2 was significantly higher in Shadow-treated trees, than in trees treated with Surround, which in turn were significantly higher than for control. However, the two spray materials significantly reduced leaf temperature, with the reduction rate being the highest in Shadow and then the second highest in Surround. However, there were no significant effects on vapour pressure deficit between treatments and the control.

TABLE 3-3. Effects of spray materials on photosynthetically active radiation (PAR), internal carbon dioxide (CO_2 int), leaf temperature (leaf T °C) and vapour pressure deficit (VPD dif) of Sensation mango trees

Treatment	PAR	CO_2 (int)	Leaf T °C	VPD (Dif)
Control	1 522.70 ab	381.88 c	31.892 a	11.371 a
Surround	1 489.00 b	390.88 b	30.964 b	10.704 a
Shadow	1 596.60 a	403.72 a	29.800 c	11.269 a

[y]Treatment means in each column followed by the same letter were not different (P≤0, 05) according to least significant difference test.

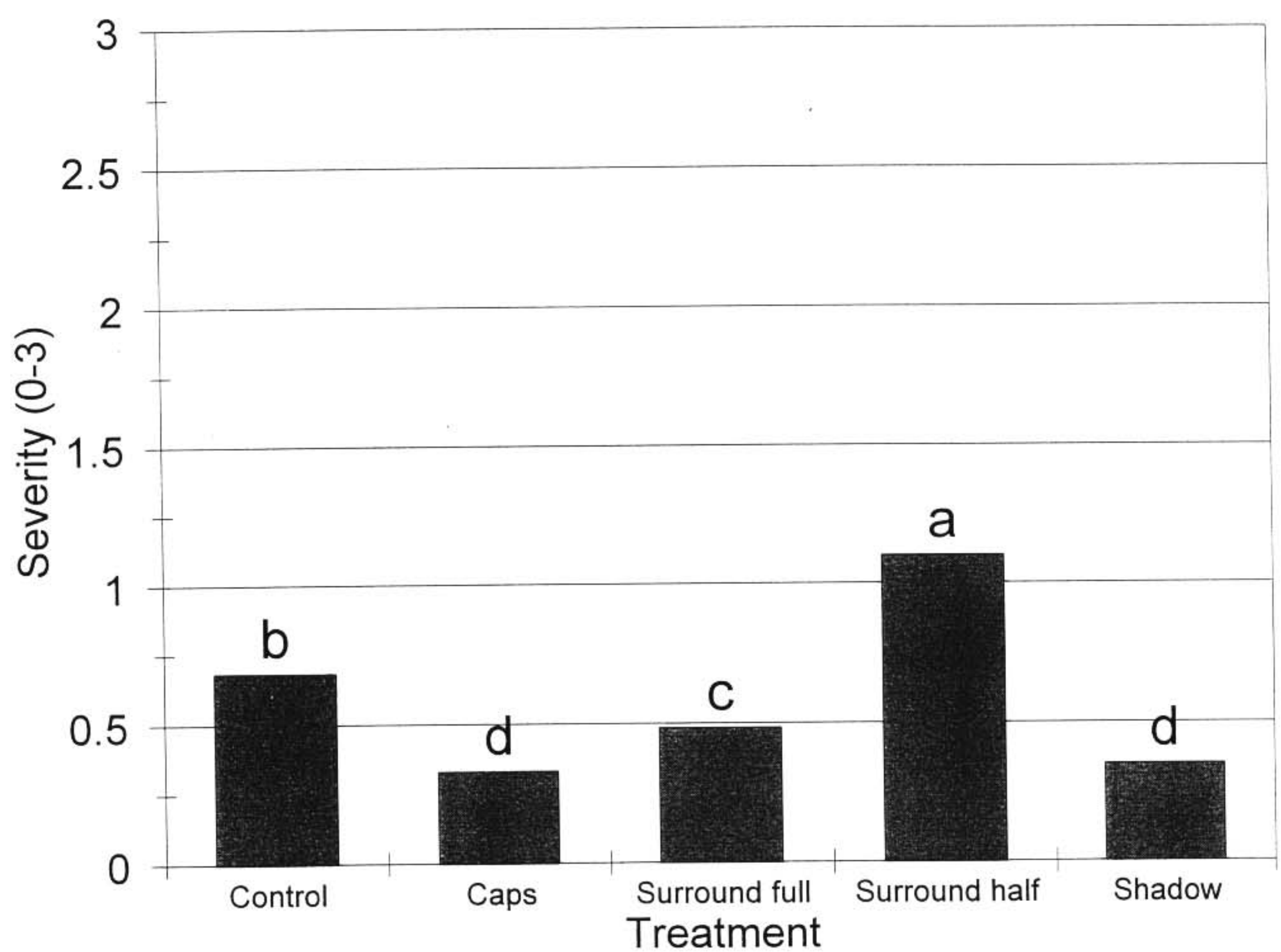
3.3.2 Post harvest evaluation of spray materials

3.3.2.1 Effects on sunburn

Fruit evaluation was carried out soon after removal from cold storage. Effects of various sunburn control materials on mango sunburn are shown in Figure 3-2. Severity of post-harvest sunburn on fruits was highest on Surround half, followed by control and Surround full; but was lowest in cap and Shadow treatments.

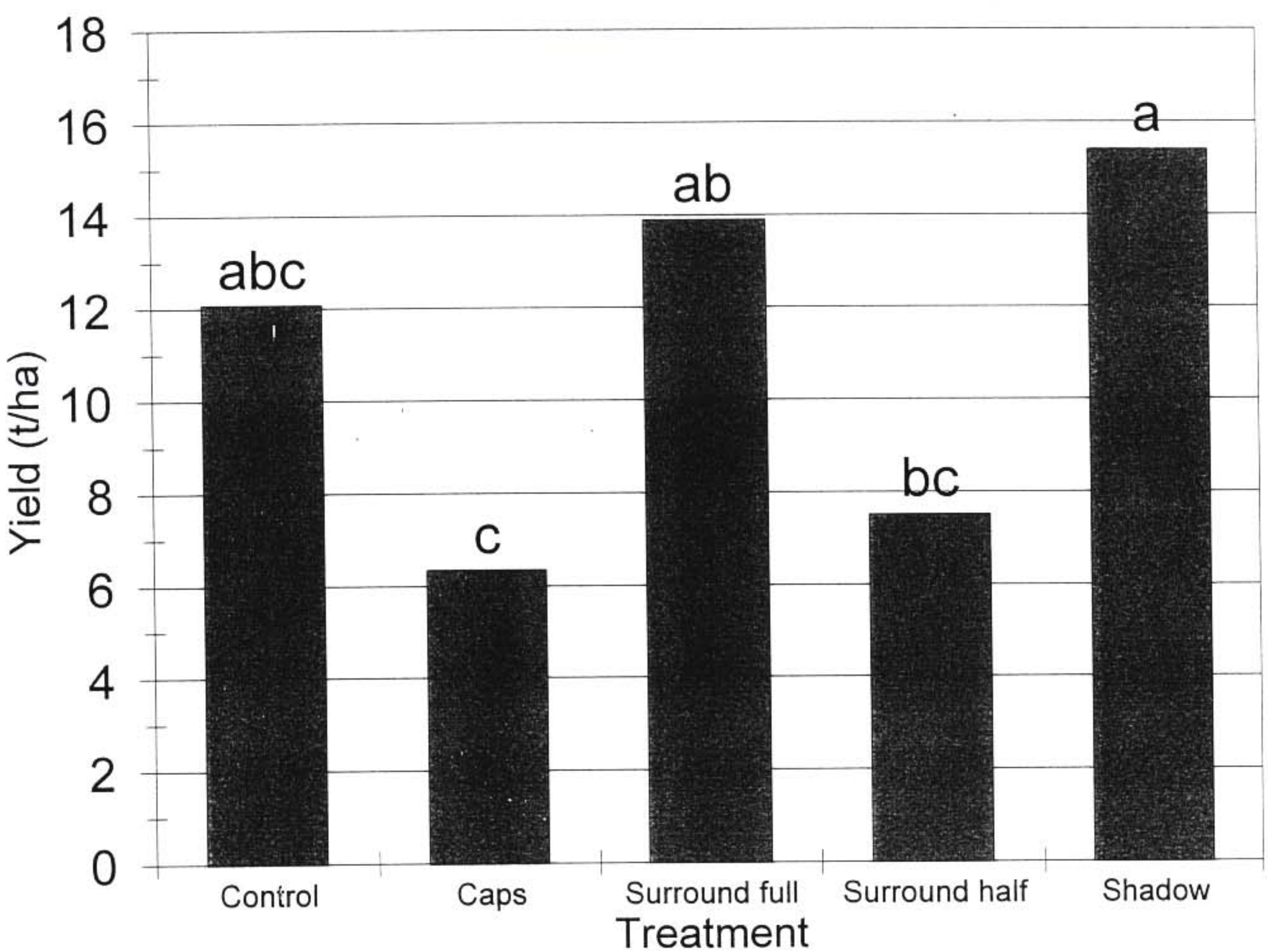
3.3.2.2 Effects on productivity

Effects of various sunburn control materials on yield of 'Sensation' mango fruits are shown in Figure 3-3. None of the sunburn control materials differed significantly from the control. However, caps produced significantly lower yields than Surround full and Shadow treatments.



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-2 Effects of various sunburn control materials on mango sunburn after 28 days in cold storage at 11°C



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

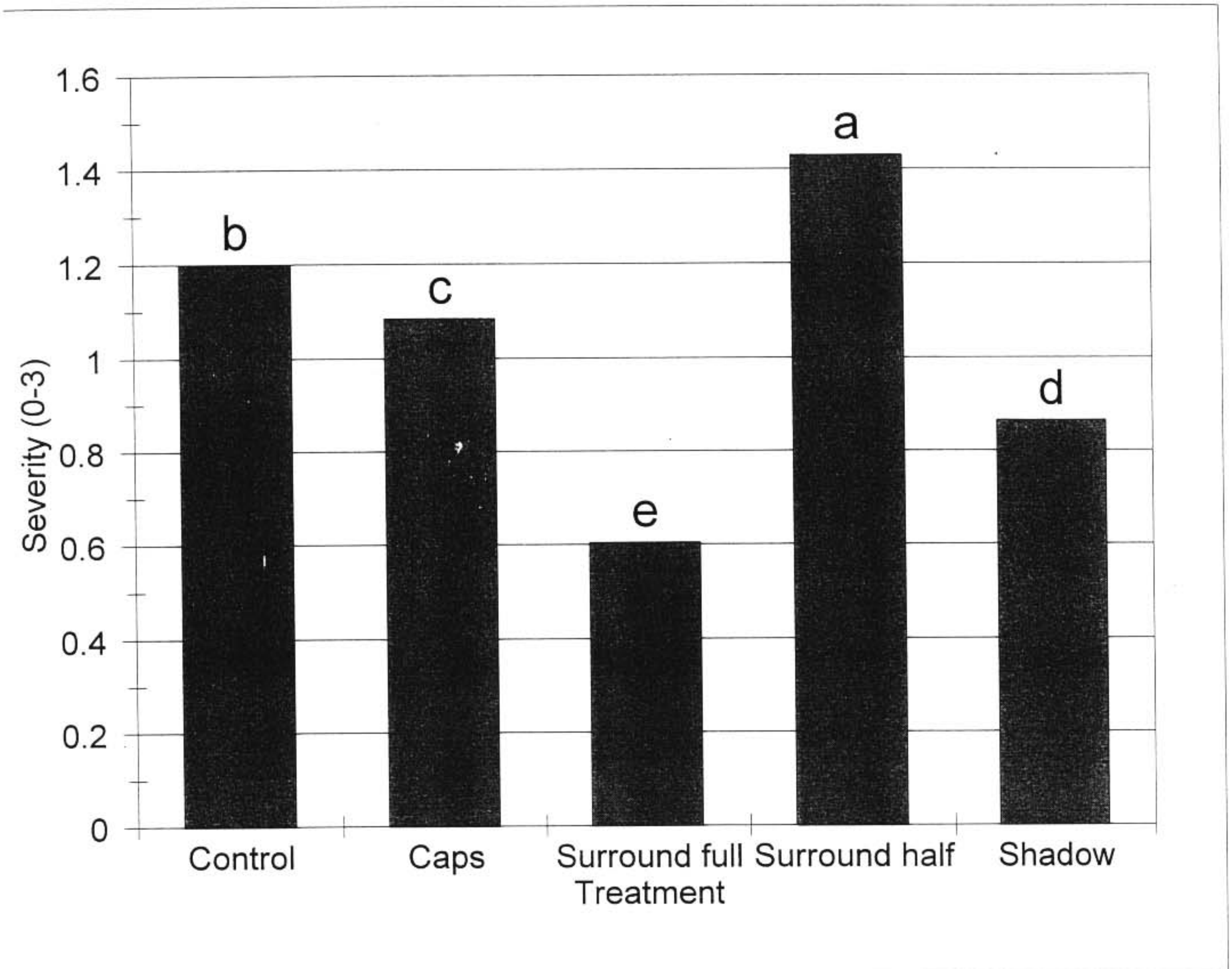
Figure 3-3 Effects of various sunburn control materials on yield of mango 'Sensation'

3.3.2.3 Effects on insects and diseases

The sunburn control materials tested had significantly different effects on thrip damage on mango fruits as shown in Figure 3-4. Severity of thrip damage on mango fruits was highest and lowest on Surround half and Surround full, respectively. Also, compared with control, severity of thrip damage was significantly lower on cap and Shadow treatments. The severity of mango scale on fruit under various sunburn control materials are shown in Figure 3-5. Compared to the control, only Surround full resulted in significantly more mango scale damage on fruits. There was no significant difference between Shadow and control in terms of scale severity but caps and Surround half resulted in significantly fewer scales than with Surround full and Shadow.

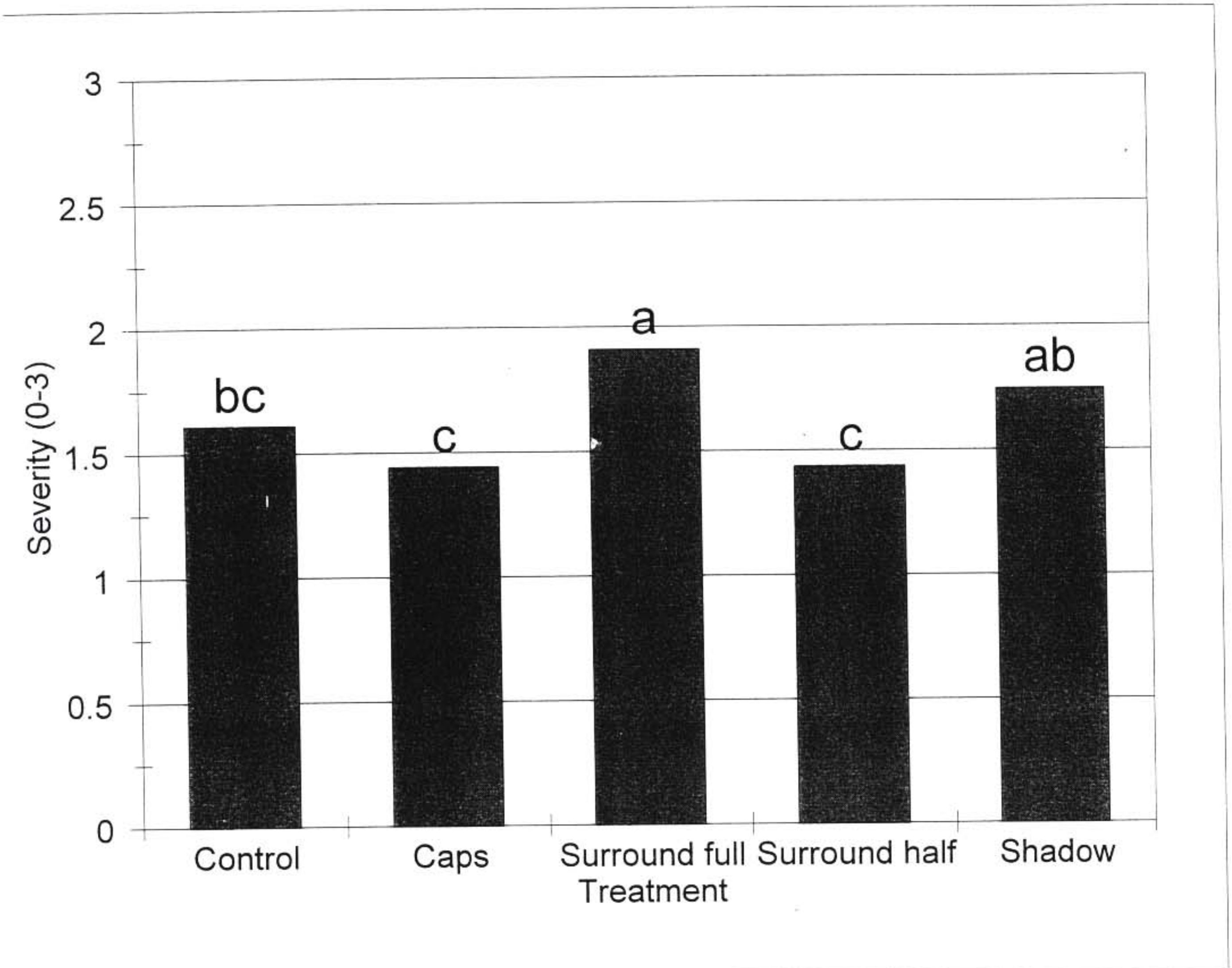
No mango weevil was observed during monitoring and fruit evaluation of any treatment, due to the stringent control program adopted by farm management.

Effects of various sunburn control materials on the incidence of soft brown rot on mango are shown in Figure 3-6. Compared to the control, only caps treatment resulted in significantly higher incidence of soft brown rot on fruits. There was no significant difference between control, Surround full and Surround half in terms severity of soft brown rot on fruits.



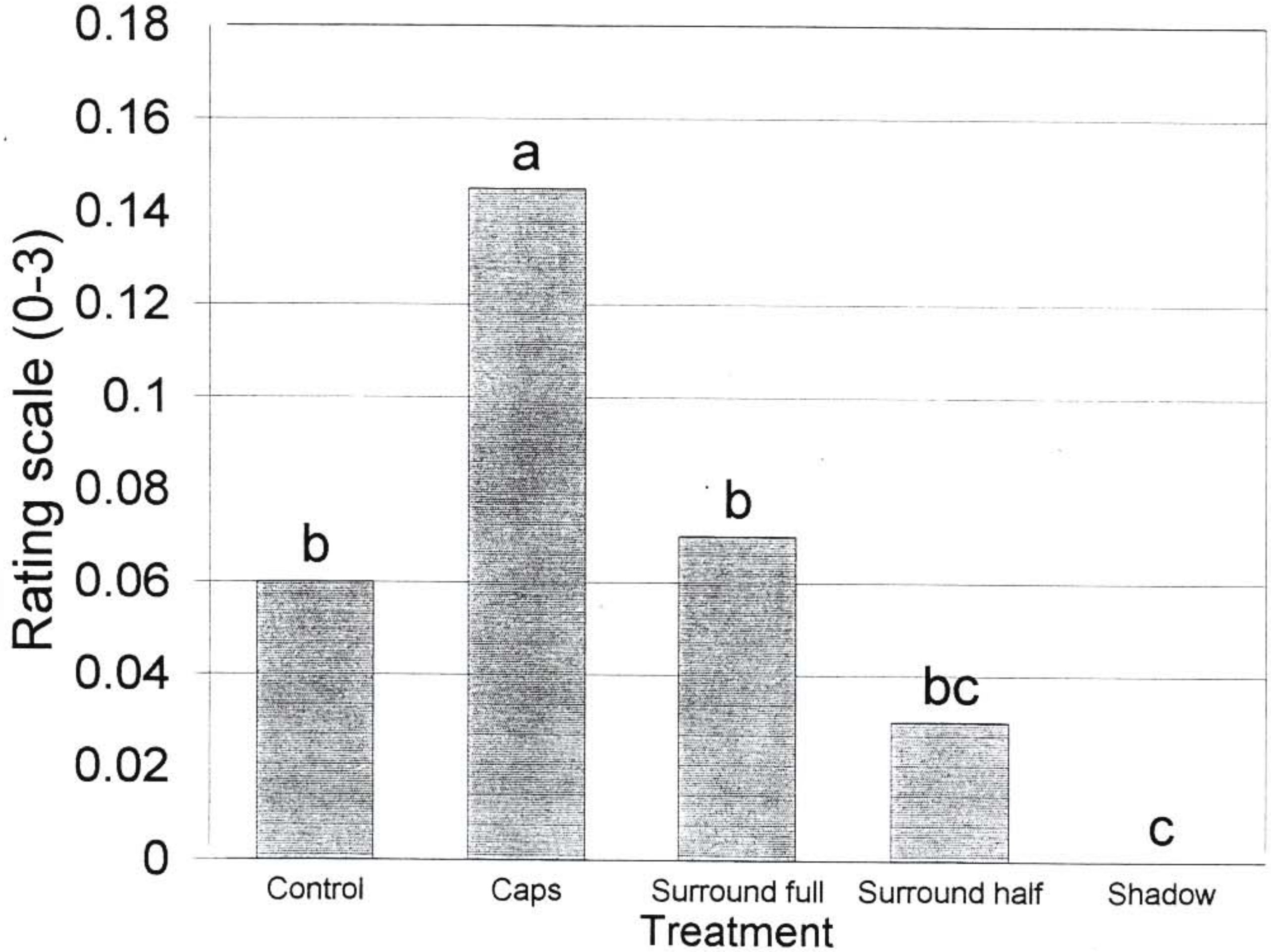
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-4 Effects of various sunburn control materials in suppressing thrips on mango fruits



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-5 Effects of various sunburn control materials on the occurence of mango scale on mango leaves



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-6 Effects of various sunburn control materials on the incidence of mango soft brown rot after 28 days in cold storage at 11°C

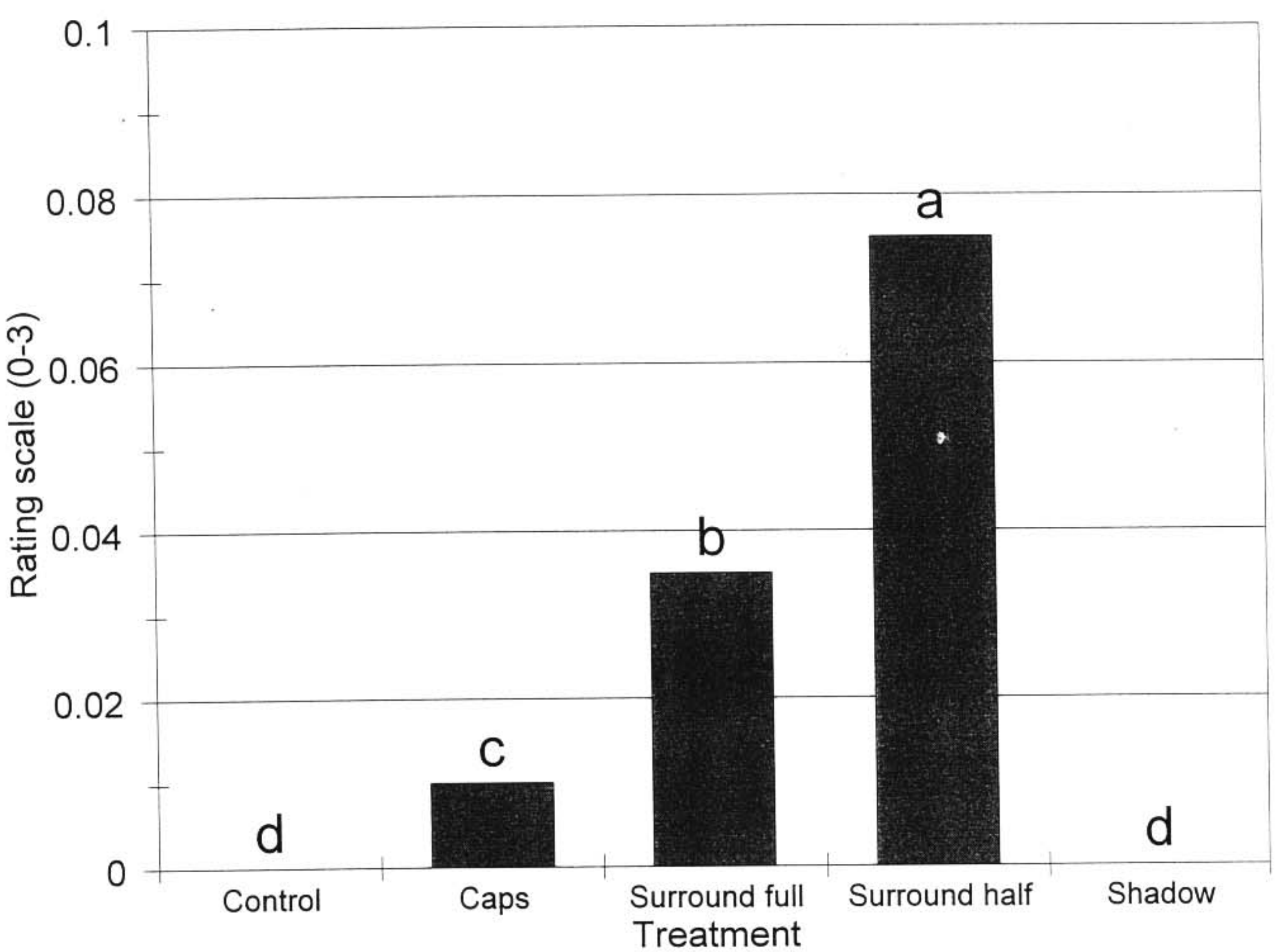
However, Shadow treated fruits were free of soft brown rot disease when compared to other treatments. Also, there was no significant difference between Surround half and Shadow in terms of soft brown rot severity. Effects of various sunburn control materials on anthracnose of mango fruits are shown in Figure 3-7. Control and Shadow treatments resulted in fruits free from anthracnose compared to other treatments. Surround half had significantly the highest incidence of anthracnose when compared to other treatments. There was a significant difference between caps and Surround full in terms severity of anthracnose on fruits.

3.3.2.4 Effects on lenticels

Effects of various sunburn control materials on lenticel damage on mango fruits are shown in Figure 3-8. Shadow had significantly the lowest incidence of lenticel damage on fruit, when compared those of the control, caps and Surround half. Surround full and Shadow had significantly had the lowest incidence of lenticel damage on fruits, when compared to the control. There was a significant difference between Surround and Shadow in terms of lenticel severity on fruits.

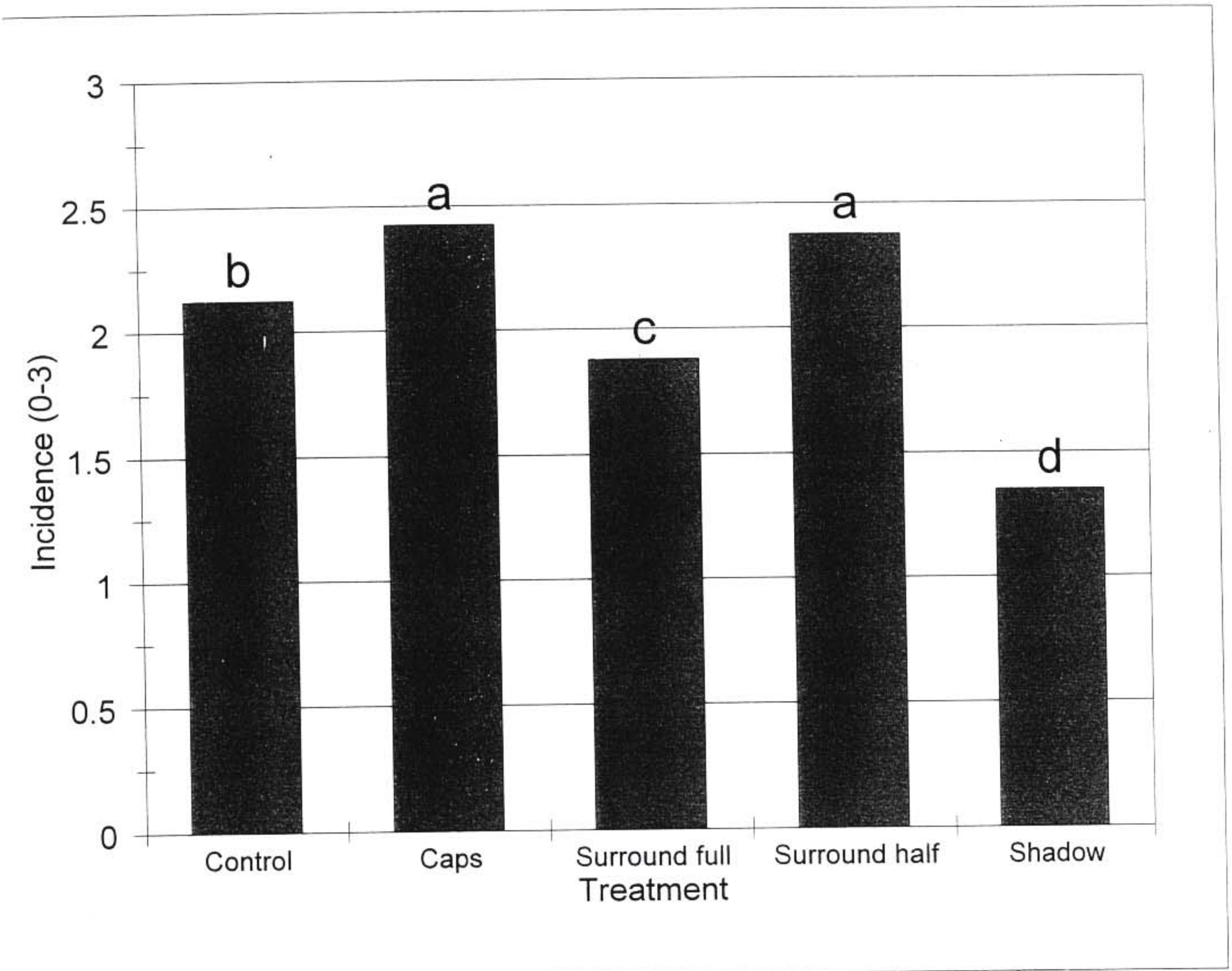
3.3.2.5 Effects on external colour development

Effects of various sunburn control materials on colour development of mango fruit is shown in Figure 3-9. Shadow treatment resulted in significantly superior



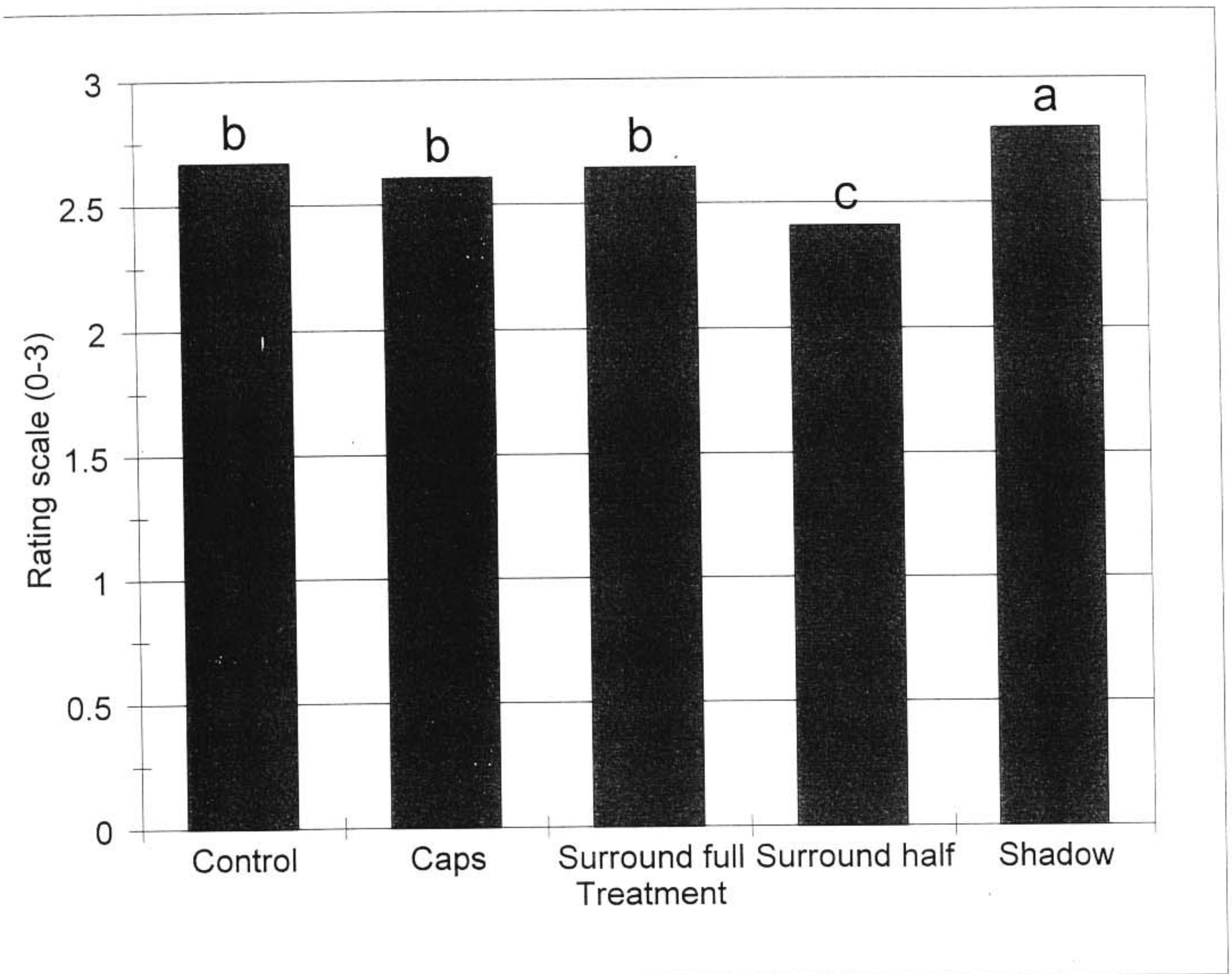
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-7 Effects of various sunburn control materials on anthracnose after 28 days in cold storage at 11°C



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-8 Effects of various sunburn control materials on lenticel damage of mango fruits after 28 days in cold storage at 11°C

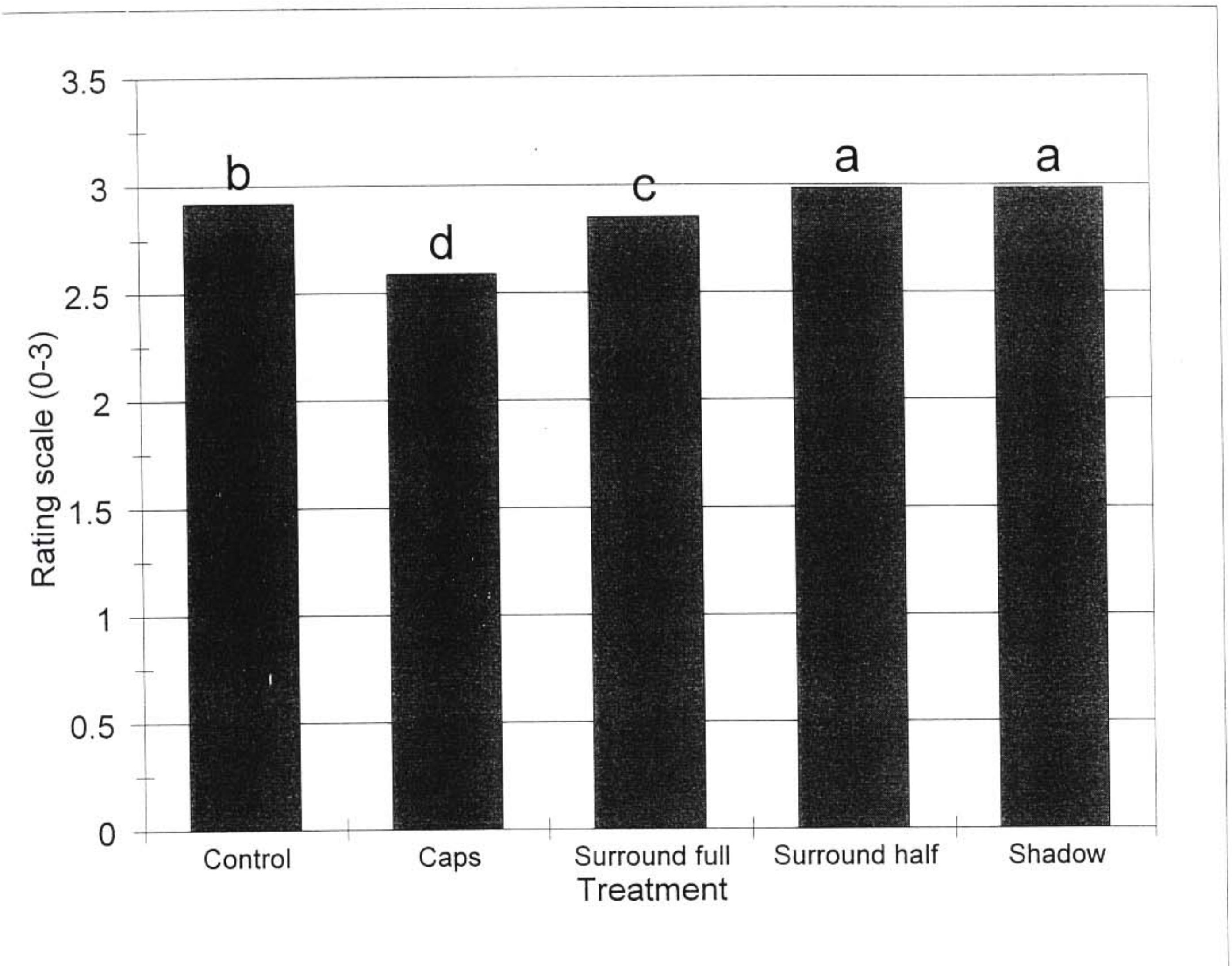


Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-9 Effects of various sunburn control materials on colour development of mango fruit after 28 days in cold storage at 11°C colour development compared to any other treatment. When compared with the control, caps and Surround full had no significant effect on external colour development, whereas Surround half significantly reduced external colour development. Effects of various sunburn control materials on background colour of fruit are shown in Figure 3-10. Shadow and Surround half significantly improved the background colour compared to other treatments. However, Surround full and caps had a significantly negative effects on blush development, compared to the control and Surround half and Shadow. Background colour was worst on fruits covered with caps.

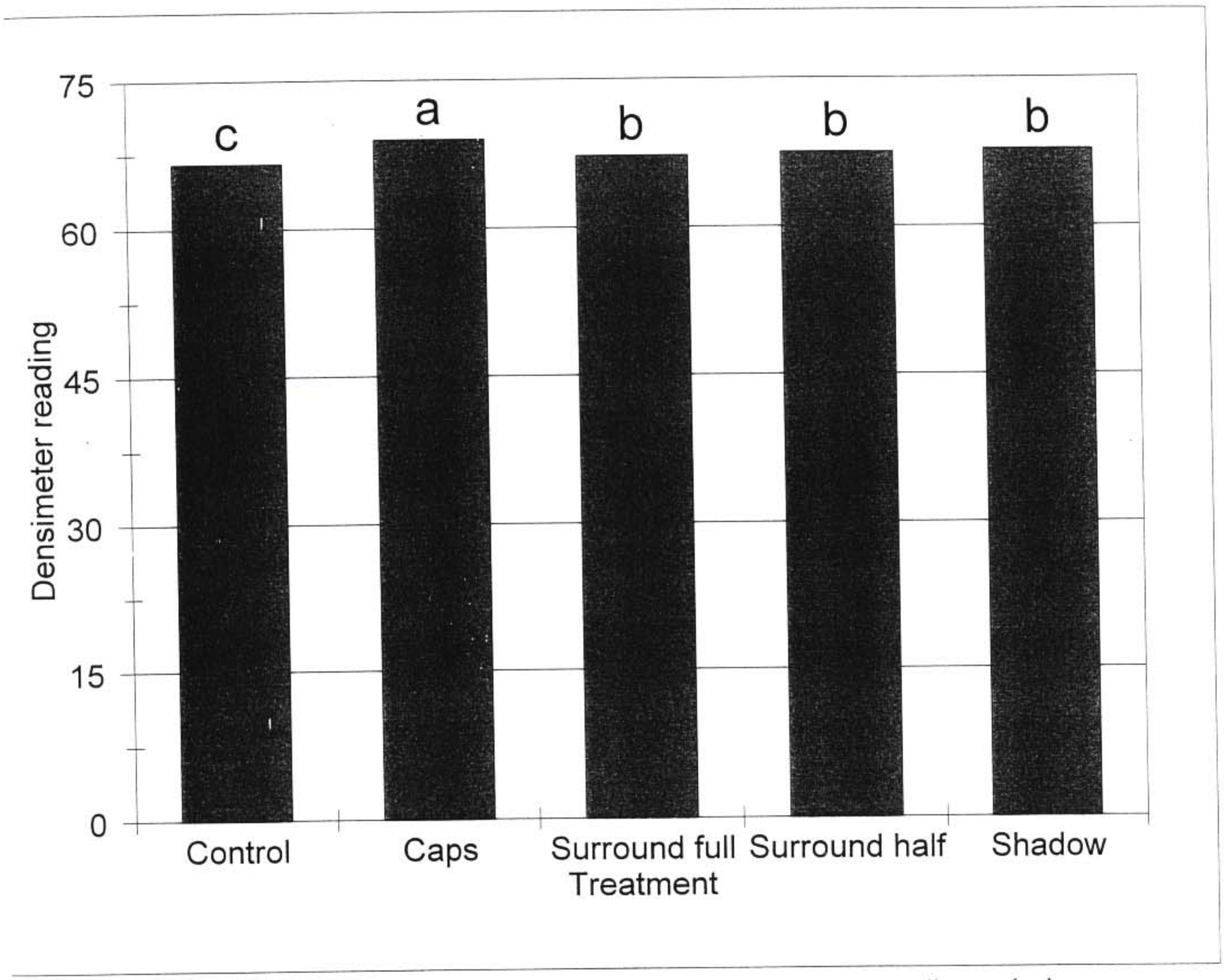
3.3.2.6 Effects on firmness, internal disorders and taste

Effects of various sunburn control materials on fruit firmness are shown in Figure 3-11. Sunburn control materials differed significantly from the control. Cap treatment had significantly hard fruit upon removal from cold storage, when compared to Surround full, Surround half and Shadow. Surround full, Surround half and Shadow did not differ significantly from each other in terms of the firmness of the fruit. Effects of various sunburn control materials on internal colour development of mango fruits are shown in Figure 3-12. Internal evaluation of fruits showed that internal colour development was uniform in all treatments, except with Surround full, where colour development was significantly poorer.



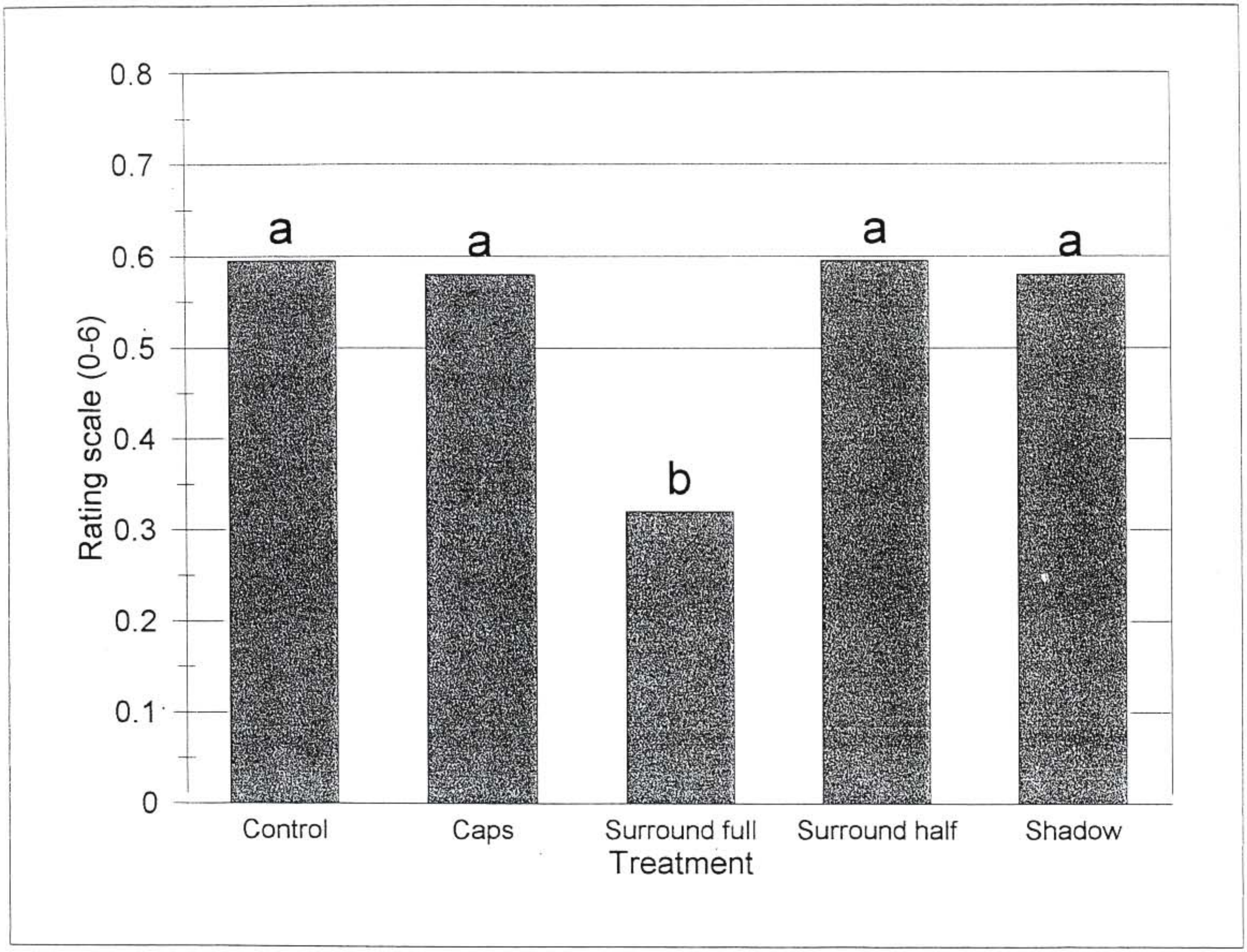
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-10 Effects of various sunburn control materials on background colour of the fruit after 28 days in cold storage at 11°C



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-11 Effects of various sunburn control materials on fruit firmness after 28 days in cold storage at 11°C



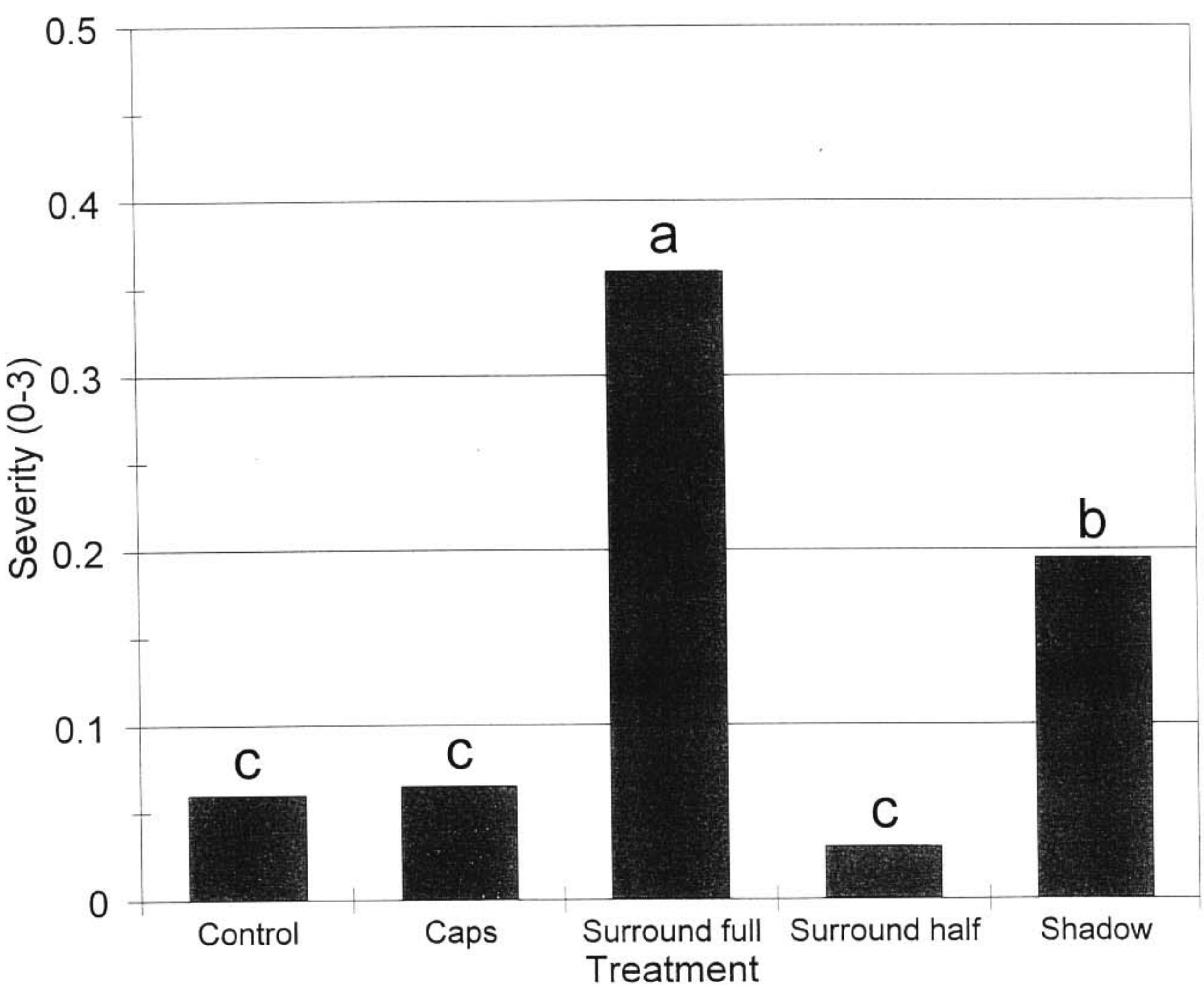
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test.

Figure 3-12 Effects of various sunburn control materials on the internal colour development of fruits after 28 days in cold storage at 11°C

Effects of various sunburn control materials on the occurrence of internal breakdown of fruit are shown in Figure 3-13. Compared to the control, Surround full and Shadow resulted in fruit with significantly the highest severity of internal breakdown. There was a significant difference between Surround full and Shadow treatments in terms of internal breakdown severity. Surround half had the lowest severity of internal breakdown but did not differ significantly to the control and caps.

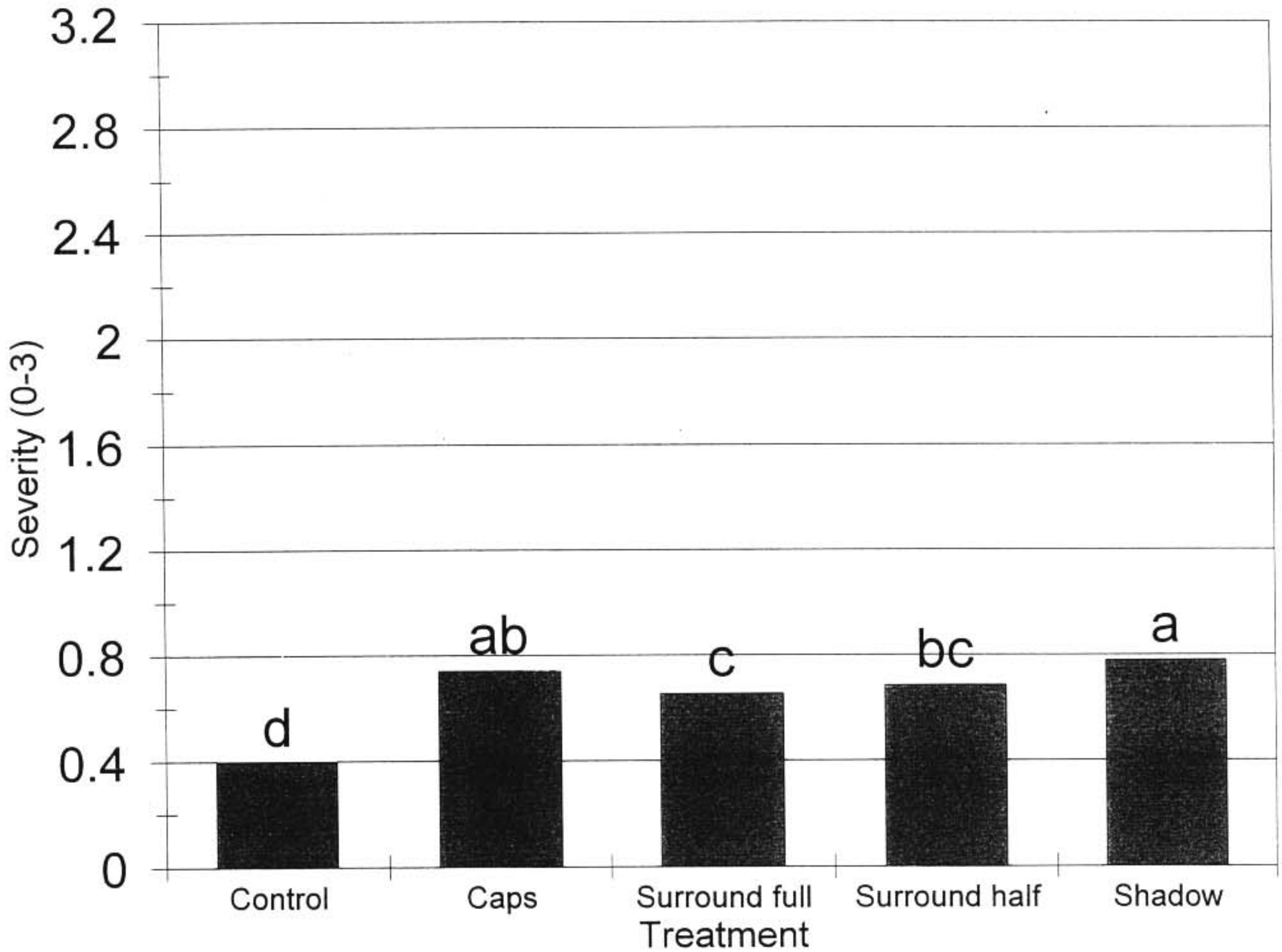
Effects of various sunburn control materials on jelly seed development are shown in Figure 3-14. Compared to the control, Shadow and cap treatments had significantly the highest incidence of jelly seed. There was no significant difference between Surround full and Surround half in terms of development of jelly seed severity. Control treatment had significantly the lowest development of jelly seed, but caps and Shadow did not differ significantly in terms of jelly seed development. Effects of various sunburn control materials on mango sweetness are summarized in Figure 3-15. Compared to the control, Surround half and caps significantly improved the brix (sugar content) of mango fruit. Also, Surround full had significantly high sugar content, when compared to the control. Control and Shadow treatments had significantly the lowest sugar content, when compared to other treatments. Caps and Surround half did not differ significantly im terms of sugar content. There was no significant difference between control and Shadow in terms of sugar content or brix.

Effects of various sunburn control materials on taste of mango fruit are shown in Figure 3-16. Compared to the control, Surround full had significantly



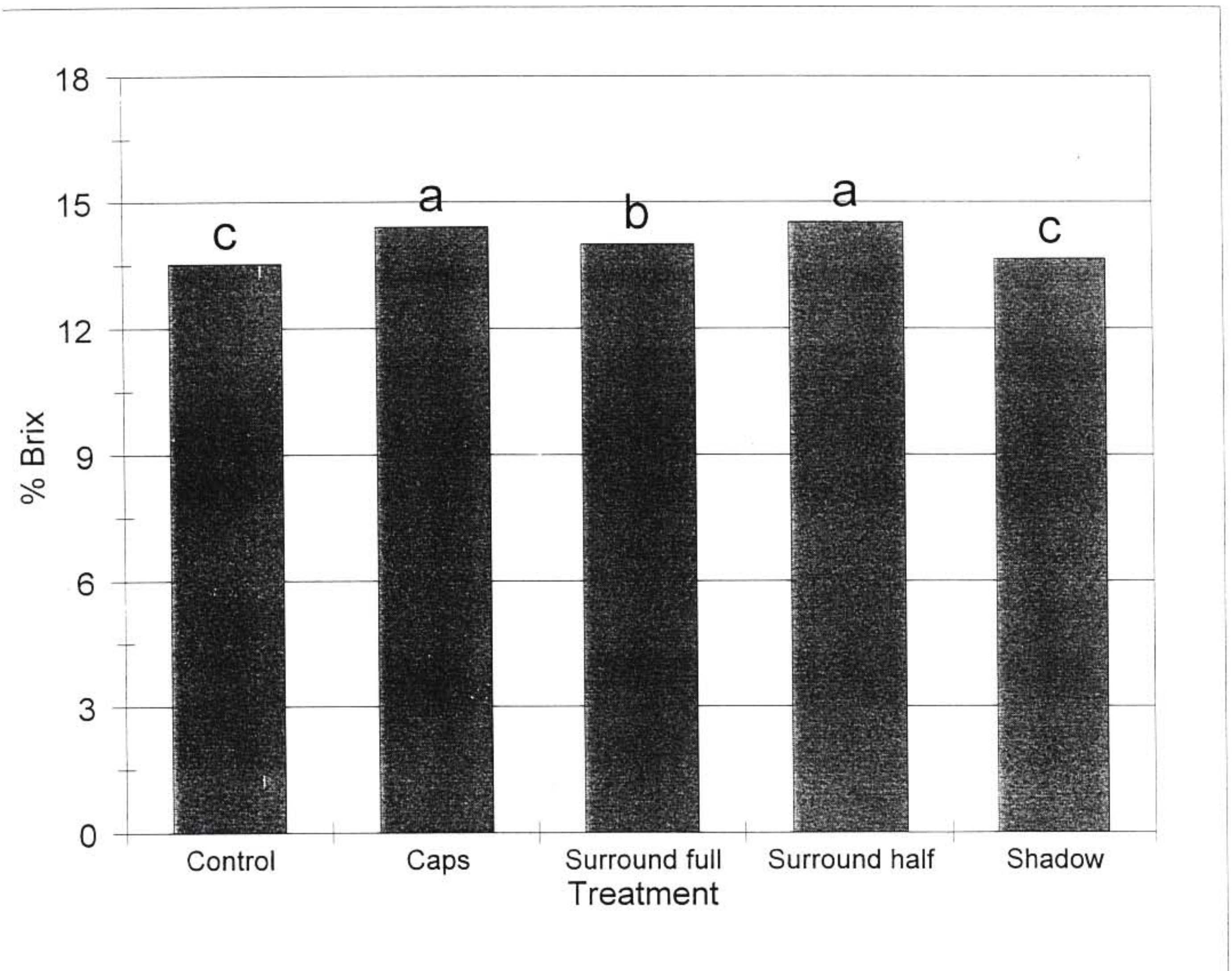
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-13 Effects of various sunburn control materials on the internal breakdown of fruit after 28 days in cold storage at 11°C



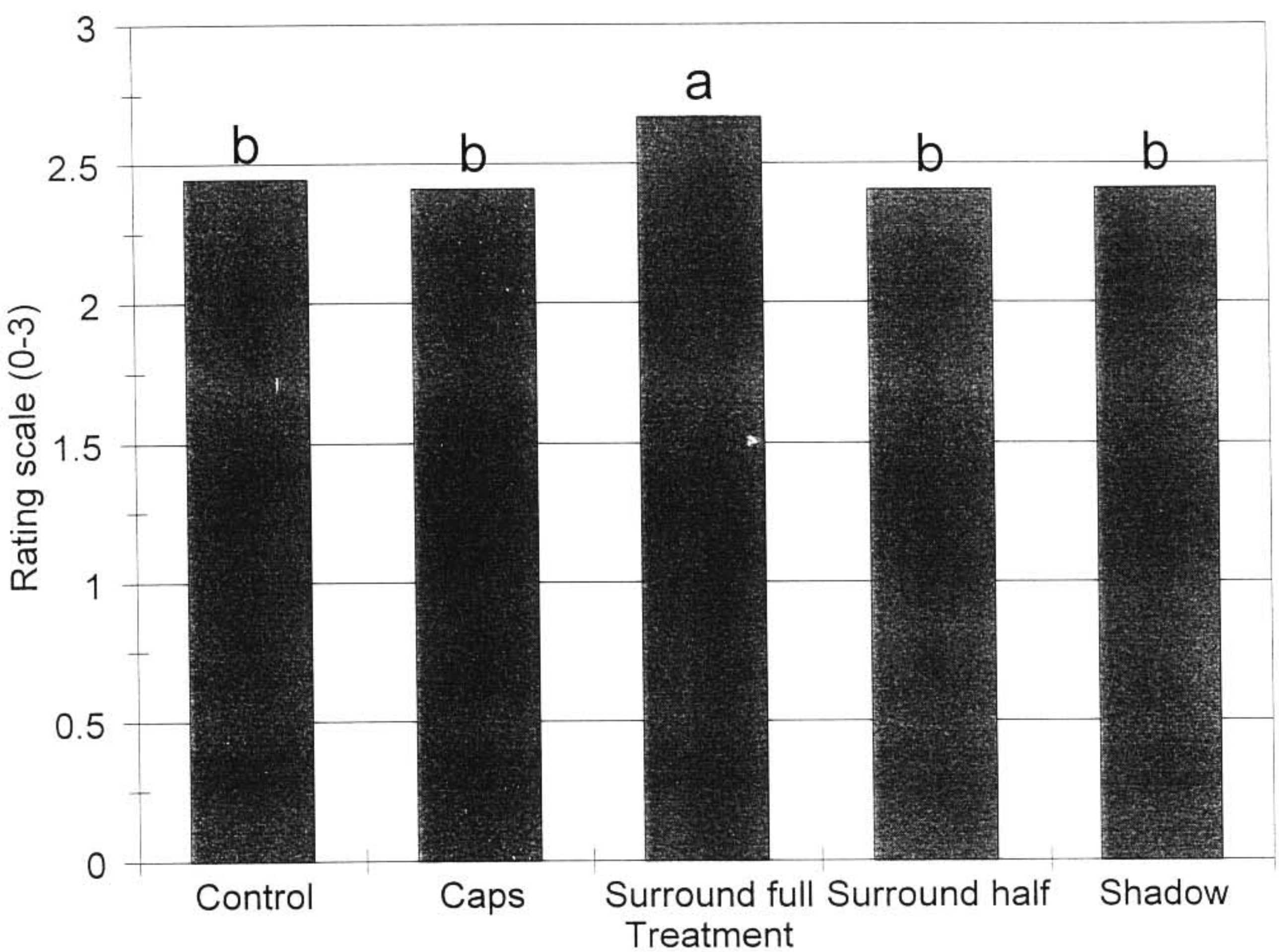
Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-14 Effects of various sunburn control materials on the development of jelly seed in mango after 28 days in cold storage at 11°C



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-15 Effects of various sunburn control materials on the sweetness of mango fruit after 28 days in cold storage at 11°C

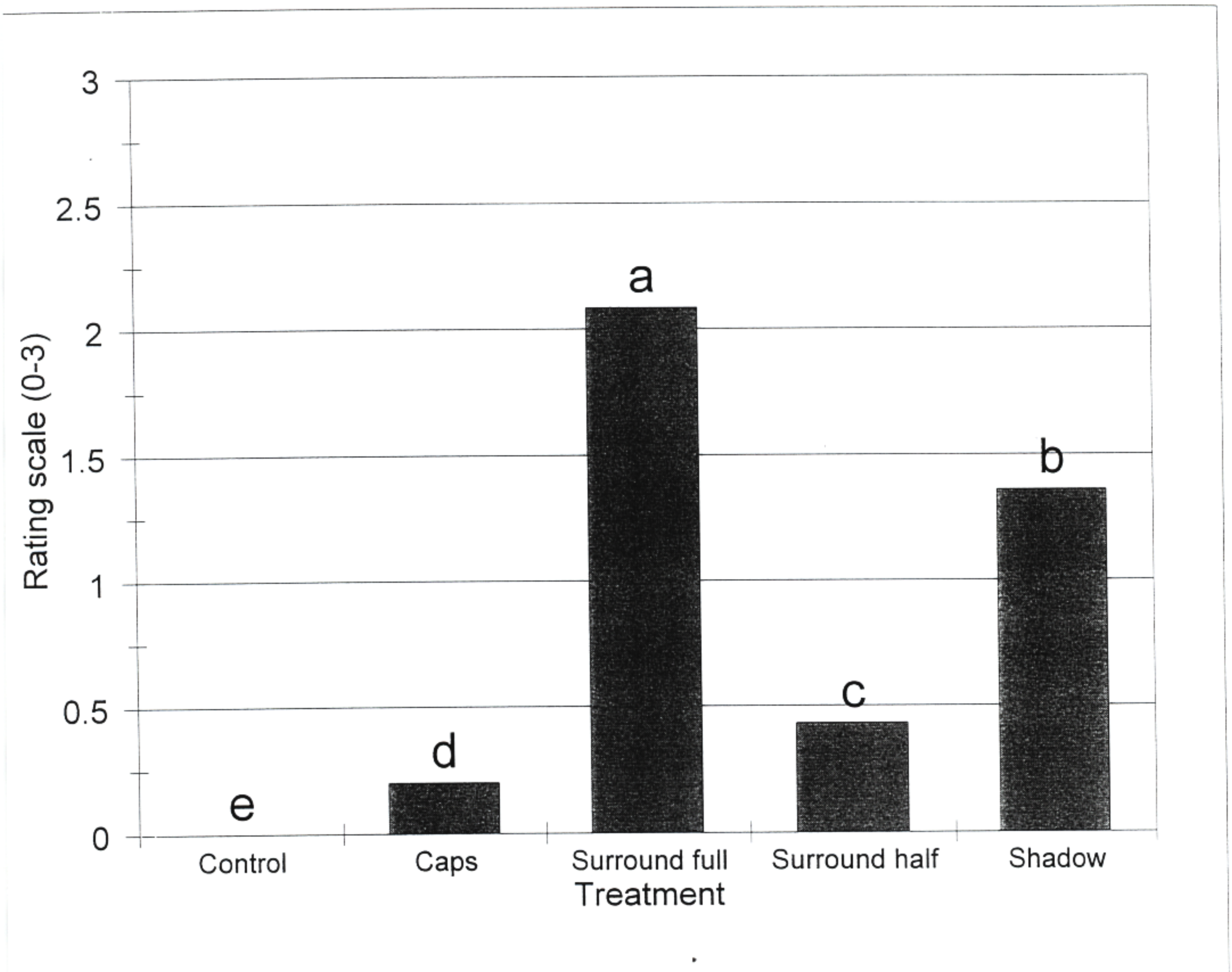


Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-16 Effects of various sunburn control materials on the taste of mango fruit after 28 days in cold storage at 11°C improved the flavour of 'Sensation' fruit. Control, caps , Surround half and Shadow did not differ significantly in terms of the flavour of 'Sensation' fruit.

3.3.2.7 Spray residues on fruits

Effects of various sunburn control materials on the visual appearance of mango fruits are as shown in Figure 3-17. All sunburn control materials differed significantly from the control. Surround full and Shadow had significantly the highest spray residues on fruit, when compared to other treatments. During fruit evaluation, it was observed that fruits treated with Surround and Shadow were dull and not shiny after being waxed. There was a significant difference between Surround full and Shadow in terms of residue severity. Caps and Surround half differed significantly in terms of residue severity but the control was free of residue.



Means followed by the same letter were not different ($P \leq 0.05$) according to the least significant difference test

Figure 3-17 Effects of various sunburn control materials on the visual impression of mango fruit after 28 days in cold storage at 11°C

Chapter 4
Discussion and Conclusion

4.1 Effects of spray materials on mango fruit sunburn

The sprayed material Shadow reduced sunburn damage on mango fruits by 96%, (Figure 3-1), showing its potential as a future mango sunburn protectant. Surround full and half rates reduced sunburn by 4% and 9%, respectively. The results suggested that Shadow had the potential status of serving as sunburn protectant if other management strategies are strictly adhered to by growers who experience sunburn problems on their farms. Management strategies such as regular irrigation, which increase tree water status and the ability of the tree to transpire in relation to the prevailing climatic conditions, are important. Practical experience showed that water stressed orchards are prone to sunburn, thus, it is imperative that regular irrigation be maintained to ensure that tree water status is kept at the correct level. The results of this study confirmed those of others (Litz, 1997; Sibbet *et al.*, 1992) who showed that sunburn problems are not easily controlled, although they can be alleviated by using whitewash.

A large number of fruits treated with Surround full and half rate suffered from sunburn because those materials came off the fruits when it rained, exposing fruits that were previously covered. The efficacy of that spray material was found to be insufficient under summer rainfall conditions.

Sunburn caps increased fruit abscissions, thus, leading to lower yield (Figure 3-3). However, caps reduced sunburn damage on fruit, and Le Lagadec (1999) reported similar results, on Kent, where fruits fitted with caps had less sunburnt fruits, but decreased yield. In Southern Hemisphere , most sunburnt fruits were found on the north and north western sides of the tree canopies (Conradie, 2000; Bergh *et al.*, 1980; Van den Ende; 1999; Roe and Morudu, 1999).

4.2 Effects of spray materials on mango fruit yield

The spray materials Shadow, Surround full and Surround half rates tested in this study did not have a negative effect on the productivity of mango trees. Shadow gave the highest yield followed by Surround full rate. The results of the study agreed with previous reports that increased yield was observed in some crops following the application of whitewash. For instance, Yalbin increased yield of artichoke (Basnizki and Evenari, 1974), rutabagas (Lowery *et al.*,1990) and sorghum (Stanhill *et al.*,1976). Also, Moreshet *et al.* (1979) reported that whitening the canopy of cotton crops with kaolin increased yield by 13%. However, Marco (1986) observed that whitewash sprays decreased yield of potato tubers.

4.3 Effects of spray materials on photosynthesis

Spray materials evaluated in the study did not have a negative effect on photosynthetically active radiation in mango trees. Eveling (1969) showed that spraying stockalite clay to leaves of beans increased the transpiration rate, implying that the materials had low effects on stomatal aperture.

In the study, it was observed that heavy scale infestation on turned leaves yellow, leading to lack of photosynthesis. Poor tree conditions resulted in delayed flushing, subsequently, leading to poor flowering or none at all. Further, applications of reflectant treatment were not approved by the farm manager at Constantia Estate because of fear of losing trees due to the after-effects of applying the used spray materials.

4.4 Effects of spray materials on insect feeding on fruits

The abrasiveness of Shadow and Surround layer on fruits appeared to discourage feeding by thrips. Mango scale was difficult to scout for due to a white layer of Shadow and Surround that covered the leaves of mango trees. A high percentage of mango scale on leaves was observed after harvest. Spray materials were abrasive by nature and might cause insects to dessicate and die, at both sampling times, and the percentage of scale populations seemed to be low (Table 3-2; Table 3-5), but increased after harvest. Most effective insect killing spray materials had been reported to be nonsorptive or sorptive particles on termites (Ebeling and Wagner, 1959), granary weevil larvae (Alexander *et al.*, 1944) and beetles (David and Gardiner, 1950). The primary mechanisms of action were the partial removal of the outer cuticle through abrasion by nonsorptive particles (Kalmus, 1944; Wigglesworth, 1944).

Marco (1986) also found that whitewashes such as kaolinite repelled aphids and leafhoppers. Under caps treatment thrip damage was severe, because fruits did not receive mineral based particles that hindered their movement due to their abrasiveness.

During the initial stages of monitoring mango scale activities, it was observed that the occurrence of female mango scales on leaves treated with spray materials Surround full, Surround half and Shadow was low. As the fruit matured mango scale populations increased in trees treated with spray materials. It might be suggested that severity of scale damage on fruit at harvest was due to a number of crawlers that fed on fruits, because female scale penetrated the plant tissue with their mouth parts and fed on the same spot for the rest of their lives. Crawlers of mango scale migrated from leaves and twigs to fruit during November/December as reported by De Villiers (1998). Leaves infested with mango scales turned yellowish, causing the plant tissues to die off. Mineral particles originating from quarrying, open-pit mining and road traffic were reported to decrease plant productivity and increase aphids, pests and fungal infections (Farmer, 1993). Also, dust had been implicated in reducing plant productivity and inducing arthropod pest outbreaks on plants (Glenn *et al.*, 1999). Trees and plants along dirt roads that became covered by road-dust had been reported to be susceptible to phytophagous mite and scale outbreaks because dust particles inhibited natural enemies of these pests (Debach, 1979). Mango trees sprayed with Surround and Shadow defoliated due to scale depletion of chlorophyll from leaves. Mango trees did not flower during the normal flowering period following the application of treatments, but instead they produced new shoots, which was a major disadvantage of these spray materials.

4.5 Effects of spray materials on infection of fruits by diseases

Fruits treated with Shadow were not infected by post-harvest diseases anthracnose and soft brown rot, while fruits that received spray materials Surround full and Surround half rates were sensitive to anthracnose (Figure 3-6; 3-7). A similar observation was made by Marco *et al.* (1994), who reported that whitewashes reduced the incidence and severity of powdery mildew in squash.

4.6 Effects of spray materials on post-harvest physiological disorders of fruits

The spray material Shadow enhanced the colour and blush development of mango fruits, while Surround full did not have an influence on colour and blush development of fruits. However, Surround half reduced colour development, but improved the blush development on fruits. The results suggested that both Surround and Shadow spray materials did not cause fruits to remain greener even after reaching industry maturity level. Most growers and researchers at the inception of the study were concerned that covering fruits with whitewash would make fruits to remain green even if they were matured. Brooks (2000) reported different results where she found that whitewashed apple fruits were greener than those of the controls, and blush development was low.

In this study spray materials Surround full and Shadow had the highest severity of internal breakdown of mango fruits as shown in Figure 3-13. Surround half rate did not have an influence on the internal breakdown of mango fruits. Also, the spray materials improved the taste of Sensation fruit, and enhanced the development of jelly seed disorders. Van den Ende (1999) reported flesh breakdown of sunburnt apple fruits after storage.

4.7 Effects of spray materials on fruit residues

Removing whitewash from the fruit in the packing process was a difficult exercise, and fruits remained dull and not shiny after waxing. Reflectant residues remained around the pedicel, which was in agreement with Brooks (2000), who found that removing whitewash material from apple fruits after harvesting was difficult.

4.8 Conclusion

At Constantia Estate, it was observed that heavy scale infection turned leaves yellow leading to lack of photosynthesis. Poor tree conditions delayed flushing, subsequently leading to non-flowering of trees. Presently, trees treated with whitewash are being monitored to observe whether they will flower after the normal flowering period. The application of the treatments was discontinued because producers where the study was conducted were scared to loose their trees due to the after-effects of applying these spray materials. Deciduous fruits lose leaves in winter when entering a rest phase, thus, defoliation and yellowing of apple leaves enhance leaf drop. Leaf drop reduces the cost of spraying a defoliant to force the trees into dormancy. In case of evergreen trees such as mangoes, heavy defoliation may lead to various physiological complications in the life of the plant.

Shadow has the potential status for use by mango growers as a whitewash spray material against sunburn because it did not wash-off the fruits when it rained. In this study, nine sprays of spray materials were applied to mango trees during fruit development until harvest, while the cost of spraying escalated, because of a bi-weekly fungicidal sprays which was part of the producers' management program. Against this background, it may be suggested that two applications would be necessary, from golf ball sized and at greater than tennis ball sized fruit stage, which is 8 weeks after the initial application. Growers should ensure that they keep the population of mango scales low throughout the year. Removal of spray materials in the packing process need a serious attention to ensure that reflectants around the pedicel would not scare the consumers. Although, sunburn problems are difficult to manage, orchard and pest management strategies such irrigation and scale control should be adhered to before and after the application of Shadow. Strategies for sunburn management should be incorporated in the producermanagement-program of mango fruits. Multidisciplinary sunburn management approaches are the key for managing sunburn problems.

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