Effect of Bioregulators on Apple Yield and Quality Attributes

G. Ouma and F. Matta

Department of Horticulture, Maseno University, Private Bag, Maseno, KENYA.

ABSTRACT

Experiments were conducted in 1995 and 1996 to investigate the effect of the two bioregulators; Accel and Carbaryl, sprayed two weeks before bloom on Apple fruit set, yield and quality and to relate the degree of fruit set reduction to the yield of three Apple cultivars namely, 'Empire', 'Jon-A-Red' and 'Braeburn'. The treatments comprised Accel 25 ppm, Accel 50ppm, Accel 75ppm and Carbaryl 0.05%, Carbaryl 0.1%, Carbaryl 0.2% and unsprayed control.

Trials conducted for two years indicated that Accel and Carbaryl reduced the fruit set of three Apple cultivars as shown by the lower number of fruit per limb cross sectional area on the sprayed trees compared to the unsprayed trees. Yield was significantly increased by the treatments and so were the fruit quality parameters such as soluble solids (^{0}brix), pH, mean weight and percent fruit color. However, the treatments had no effect on the number of seeds in the fruit, fruit length, fruit diameter and fruit length to diameter ratio.

Finally it was observed that the most effective concentrations in reducing the fruit set were: Accel 50ppm, Accel 75ppm, Carbaryl 0.1% and Carbaryl 0.2% and they had generally high yields.

1.0 INTRODUCTION

Fruit set does not occur with all the flowers. The extent of this natural shedding varies with species. Large fruited types such as apple may shed 95% or more of their flowers and young fruit (Westwood, 1993). Pollination is a requirement for fruit set in most flowers. After pollination a pollen tube traverses the style, penetrates the micropyle and fertilization of the egg takes place. Hormonal stimulus from the young developing embryo prevents the fruit from abscising and causes the ovary and adjacent tissues to enlarge into a developing fruit.

It appears that either auxin, gibberellins or cytokinins can directly cause fruit set or the developing embryo can stimulate the production of auxin which influences fruit set (Westwood, 1993). Other sites of auxin synthesis are young fertilized ovules, fruit, and the tips of shoots and roots. It has been observed that plant hormones may act synergistically in affecting fruit set. With apples maximum synergism occurs when the auxin, gibberellins and cytokinins are used together (Westwood, 1993).

Under optimum conditions most trees will set more fruits than needed for a full crop, therefore, fruit thinning is done. Fruit thinning is done to reduce limb breakage, increase fruit size, improve fruit color and quality and stimulate floral initiation for next years crop (Westwood, 1993). Thinning is defined as the removal of certain flowers or clusters of flowers or individual fruits after fruit set and natural dropping has occurred (Valenzuela, 1992). Increasing the leaf to fruit ratio by removing some of the fruit causes the remaining fruit to be larger, but not in direct proportion to the increase in the number of leaves per fruit, leading to some yield reduction (Westwood, 1993). The practice of fruit thinning has been known for a very long time (Ryugo, 1988 cited by Valenzuela, 1992).

There are three general methods of thinning namely: hand, mechanical and chemical. Hand thinning is removing flowers or fruit. Previously, fruits were thinned to a predetermined spacing but now size thinning is preferred (Westwood, 1993). Size thinning is the selective removal of small and weak fruit irrespective of spacing with the consideration of the desired degree of thinning (Westwood, 1993). Mechanical thinning may be carried out by using a direct blast of high-pressure water from a hand-operated sprayer at or slightly postbloom. Chemical fruit thinning of apples following bloom is a standard practice to improve fruit size, quality, increase return bloom and reduce biennial bearing (Williams, 1979). A satisfactory thinning spray program will remove enough fruit to ensure an adequate return bloom the following season. Thinning can be accomplished at bloom time and during the early postbloom period. Some postbloom chemicals are hormone types and are used to upset the natural hormone balance of the tree. Others are non-hormonal but cause stress and embryo abortion (Williams, 1979).

Some of the bioregulators used for thinning apples are; ethephon (Jones *et al*, 1989, Gibberellins (Greene, 1989), Carbaryl (Wismer and Elfving, 1995) and Accel (Abbott Laboratories, 1995).

Although research has been carried out on the effect of some bioregulators on yield, fruit set and quality of apples, information on effect of Accel and Carbaryl on apple yield and quality attributes is lacking. Therefore, the objectives of this study were to investigate both the effect of Accel and Carbaryl on fruit set and the effect of Accel and Carbaryl on yield and quality attributes of Apple.

2.0 MATERIALS AND METHODS

Experimental design and treatments:

Two similar experiments were conducted using mature apple trees at the Mississippi State University Agricultural and Forestry experimental station at Pontotoc located about 7 miles South of Pontotoc in the South Central part of Pontotoc country. The soils at the station are classified as alfisol, ultisol, inceptisol and entisol orders with soils ranging from deep red and high silt to gray-having silt loam and finer textured subsoils having expansive montmorillonite clay.

The first experiment was initiated on May 15, 1996 and terminated on August 30, 1996. Spraying of the bioregulators for both experiments was done on calm clear and dry days from 11.00 a.m. to 4.00 p.m. The treatments applied were Accel 25 ppm, Accel 50ppm, Accel 75ppm, Carbaryl 0.05%, Carbaryl 0.1%, Carbaryl 0.2% and unsprayed control. These treatments were replicated three times in a completely randomised design with a factorial arrangement. Each treatment was applied to a replicate of three apple trees using a hand sprayer on whole trees two weeks after bloom. The surfactant `Tween' 20 at a concentration of 0.1% was mixed with the bioregulators to act as a wetting agent before the treatments were applied. Spraying of the trees was done to dripping point. The study was conducted on `Empire', `Braeburn' and `Jon-A-Red' apple cultivars. Recommended cultural practices for commercial apple production i.e. fertilization and pest control were followed. Fruit harvesting started at the beginning of August and ended at the beginning of September. We determined fruit set, fruit yield and quality attributes.

Fruit set:

Fruit set was determined before bloom by tagging four representative limbs of 12 to 15 cm circumference on each tree (Lombard *et al*, 1988). The number of fruits were counted after June drop which was one month after the application of the bioregulators and expressed as the number of fruit per unit limb cross sectional area.

Mean weight and yield:

A sample of 20 fruits per tree was weighed using a mettler PE electronic scale in Kilograms. Mean weight was calculated by dividing the total weight of the fruits by 20 and the yield per tree was actually determined by weighing all the fruits on the tree.

Length of fruit

This was determined by a hand caliper on a sample of 10 fruits, the length of each fruit being measured by laying it on the caliper. An average fruit length was then calculated by adding the individual lengths and dividing by 10.

Diameter of fruit

The diameter of fruits was determined by a caliper on a sample of 10 fruits. The diameter of each fruit was measured by fixing it to the caliper. An average fruit diameter was subsequently calculated by adding the individual diameters and dividing by 10.

Length diameter ratio

The length and diameter of each fruit was divided, totalled for the 10 fruits and divided by 10 to find the average length to diameter ratio for each fruit.

Seed number per fruit

The fruit were dissected at harvest time and the number of seeds of each fruit counted and totaled for 10 fruits and average seed number determined by dividing it by 10.

Percent red color:

After harvest or removal of fruits from cold storage, the fruits were wiped gently using soft cloth and color determined by placing the head of a portable colorimeter at the midpoint between the stem and the calyx of the fruit (McGuire, 1992). The meter was calibrated using a white standard before use and a sample of 10 fruits used for the determination. The type of colorimeter used was Labscan 6000 spectrocolorimeter.

Statistical analysis:

All statistical analyses were carried out using the general linear models (GLM) procedure of the statistical analysis system (SAS Institute, N. C., 1988) program package. Mean separation was done on the treatment means using the least significant difference (L.S.D.) at $P < 0.05$.

Total soluble solids:

Juice was extracted from the apples using a Mullinex juice extractor and filtered through a 28 - mesh screen. Total soluble solids was determined on the extracted juice using a Bausch and Lomb Optical refractometer (Fisher Scientific; Spring Field, N. J.) and expressed in degrees brix (^{0}Brix).

pH

The extracted juice was also used to determine pH by an accumet laboratory meter (Fisher Scientific, Spring Field, N. J.).

3.0 RESULTS

3.1 Effect of Accel and Carbaryl on Fruit set and Yield:

Fruit set was expressed as the number of fruits per square centimetre limb cross sectional area. In 1995 all the bioregulators significantly ($P < 0.05$) reduced fruit set, the magnitude of which increased with their concentrations (Table 1). The trends in fruit set reductions were Accel 75ppm, Carbaryl 0.2%, Accel 50ppm, Carbaryl 0.1%, Carbaryl 0.05% and Accel 25ppm in that order.

Although Accel 75ppm had higher fruit set reductions as compared to controls in the three apple cultivars it had correspondingly lower yields than carbaryl 0.2%, Accel 50ppm and Carbaryl 0.1% (Table 1) which had lower fruit set reductions. There was no cultivar and bioregulator interaction in 1995. The trends in yield increases did not follow those of fruit set reductions exactly, particularly at the highest bioregulator concentrations. In 1995 the yield of `Empire' was not affected by Accel or Carbaryl at any concentration (Table 1). Accel 50ppm increased the yield of `Jon-A-Red' while the remaining treatments had no effect. Yield of `Braeburn' was significantly (P< 0.05) increased by Carbaryl 0.2% and Accel 50ppm while the remaining treatments had no effect.

Table 1: Effect of Accel and Carbaryl on fruit set, yield and some quality attributes of three Apple cultivars grown at the Pontotoc Research and Extension Centre, 1995 Experiment.

Treatment	No. of PCLA	Fruit Length	Fruit Diameter	Length to Diameter ratio	Yield (Kg)	PH	^{0}Brix	Red Color (%)	Mean fruit weight (g)
`Empire'									
Carbaryl 0.05%	8.33	5.90	7.13	0.83	5.60	4.97	12.00	27.50	1.70
Carbaryl 0.1%	5.40	5.83	7.33	0.81	8.40	4.43	12.80	22.90	1.80
Carbaryl 0.2%	3.13	6.43	7.55	0.83	9.60	4.42	13.30	22.70	1.80
Accel 25ppm	6.10	5.93	7.16	0.80	6.40	4.48	14.50	25.50	1.40
Accel 50ppm	4.23	6.03	6.57	0.80	5.60	4.42	14.60	25.70	1.60
Accel 75ppm	1.67	5.97	7.48	0.87	8.00	4.50	15.10	26.30	1.20
Control	11.67	5.60	6.84	0.82	4.60	4.31	12.60	7.70	1.26
`Jon-A-Red'									
Carbaryl 0.05%	7.40	5.90	7.14	0.83	0.80	4.57	13.00	19.70	0.54
Carbaryl 0.1%	4.43	5.57	6.54	0.85	1.30	4.39	15.60	24.50	0.64
Carbaryl 0.2%	3.03	6.43	7.45	0.85	1.30	4.39	15.60	24.50	0.64
Accel 25ppm	0.37	5.73	7.00	0.81	0.80	4.40	13.10	26.80	1.55
Accel 50ppm	2.07	5.87	6.61	0.88	8.50	4040	15.00	27.90	1.60
Accel 75ppm	0.23	6.13	7.24	0.83	7.70	4.60	16.00	27.50	1.26
Control	12.68	6.40	7.27	0.88	0.80	4.28	13.00	24.20	0.59
`Braeburn'									
Carbaryl 0.05%	8.37	6.00	7.17	0.80	5.90	4.30	13.50	19.00	1.58
Carbaryl 0.1%	6.07	6.30	7.57	0.85	10.50	4.51	14.10	18.50	1.66
Carbaryl 0.2%	4.43	6.18	7.18	0.87	17.80	4.28	14.80	18.50	1.76
Accel 25ppm	4.00	5.63	6.35	0.84	11.20	4.47	13.10	17.30	1.14
Accel 50ppm	5.87	6.16	7.23	0.87	17.20	4.34	13.40	17.00	0.85
Accel 75ppm	1.43	6.37	7.64	0.87	8.80	4.48	13.50	20.80	1.53
Control	12.87	6.17	7.33	0.85	4.90	4.45	12.90	19.60	1.83
L.S.D.	4.08	0.69	0.02	0.06	7.80	0.24	2.15	6.03	1.14
Significance of F tests									
Cultivar	**	NS	NS	NS	**	**	NS	**	**
PGR	**	NS	NS	NS	**	**	**	**	**
Cultivar X PGR	NS	NS	NS	NS	**	**	**	**	NS
Regression									
Linear	**	NS	NS	NS	NS	NS	**	NS	NS
Quadratic	NS	NS	NS	NS	**	NS	NS	NS	NS

** = Significant at P = 0.05; NS = Not Significant at P = 0.05; PGR = Bioregulators; PCLA = Per Cross Sectional Limb Area.

In 1996 Accel and Carbaryl at all concentrations significantly ($P< 0.05$) reduced the fruit set of all the apple cultivars except Accel 25ppm (Table 2). The trends in fruit set reduction were Carbaryl 0.2%, Accel 75ppm, Carbaryl 0.1%, Accel 50ppm, Carbaryl 0.05% and Accel 25ppm in that order.

Table 2: Effect of Accel and Carbaryl on fruit set, yield and some quality attributes of three Apple cultivars grown at the Pontotoc Research and Extension Centre, 1996 Experiment.

Treatment	No. of Fruit PCLA	Fruit Length	Fruit Diameter	Length to Diameter ratio	Yield	PH	°Brix	Mean fruit weight (g)	Number of seeds
'Empire'									
Carbaryl 0.05%	9.47	5.21	6.60	0.91	4.57	4.09	12.07	1.40	6.33
Carbaryl 0.1%	4.63	5.59	6.81	0.84	21.27	4.25	12.20	0.90	6.66
Carbaryl 0.2%	0.23	5.84	7.11	0.82	5.43	4.24	13.77	1.53	6.67
Accel 25ppm	13.97	5.63	7.07	0.80	9.37	3.76	13.40	1.14	6.66
Accel 50ppm	7.73	5.27	6.70	0.86	23.87	4.22	13.67	1.55	6.33
Accel 75ppm	3.57	6.04	6.99	0.78	13.10	4.24	14.00	1.63	7.00
Control	14.60	5.77	6.97	0.86	3.63	4.28	11.60	1.33	6.67
Jon-A-Red'									
Carbaryl 0.05%	4.43	5.28	6.63	0.80	23.43	3.52	12.97	1.13	5.66
Carbaryl 0.1%	1.80	5.43	6.43	0.84	21.77	3.97	13.77	1.27	6.33
Carbaryl 0.2%	1.63	5.40	6.57	0.79	23.47	3.99	14.20	1.28	7.00
Accel 25ppm	7.40	5.43	6.80	0.86	9.73	3.97	13.17	1.23	6.67
Accel 50ppm	2.43	5.47	6.37	0.85	25.57	4.10	14.70	1.28	7.00
Accel 75ppm	0.83	5.37	6.33	0.86	37.10	4.42	13.53	1.65	7.00
Control	8.20	5.67	6.55	0.80	2.97	3.76	11.67	1.07	5.33
Braeburn'									
Carbaryl 0.05%	7.67	5.86	6.74	0.87	17.30	4.01	12.77	1.03	6.33
Carbaryl 0.1%	5.60	5.90	6.80	0.87	22.30	4.65	14.40	1.50	6.33
Carbaryl 0.2%	1.37	6.03	7.01	0.84	18.87	4.16	12.97	1.67	7.30
Accel 25ppm	6.73	5.93	7.13	0.83	21.33	4.00	12.13	1.40	6.00
Accel 50ppm	4.97	5.45	7.20	0.76	21.47	4.59	13.70	1.62	7.00
Accel 75ppm	0.73	6.16	7.34	0.84	29.03	4.74	14.00	1.69	7.00
Control	12.33	5.93	7.13	0.83	6.00	4.03	12.07	0.95	5.30
LSD	4.03	0.61	0.86	0.15	10.61	0.56	1.46	1.19	0.30
Significance of F tests									
Cultivar	NS	NS	NS	NS	NS	NS	NS	NS	NS
PGR	**	NS	NS	NS	**	**	**	NS	NS
Cultivar X PGR	**	NS	NS	NS	NS	NS	NS	NS	**
Regression									
Linear	**	NS	NS	NS	**	NS	**	**	NS
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS

** = Significant at $P = 0.05$; NS = Not Significant at $P = 0.05$; PGR = Bioregulators;
PCLA = Per Cross Sectional Limb Area.

Conversely, the yield trends in reducing order were Accel 75ppm, Accel 50ppm, Carbaryl 0.1%, Carbaryl 0.2%, Carbaryl 0.05% and Accel 25ppm. In 1996 Carbaryl 0.2% had higher fruit set reduction in 'Empire' than Accel 75ppm while the reverse occurred in 'Braeburn' and 'Jon-A-Red'.

The yields corresponding to the fruit set reductions caused by Accel 75ppm and Carbaryl 0.2% were also high.

Accel at increasing concentrations caused increase in yields for all apple cultivars in 1996 (Table 2). This compares unfavourably with carbaryl whose relationship with yields was not as clear-cut. There were significant interactions between cultivar and bioregulators in 1996. Overall, Carbaryl 0.1% and Accel 50ppm were the only treatments which increased the yields of 'Empire' in 1996 and all the bioregulator treatments increased the yields of 'Jon-A-Red' and 'Braeburn'.

3.2 Effect of Accel and Carbaryl on Some Fruit Quality Attributes

Mean weight

The mean weights of the fruits were either significantly ($P< 0.05$) increased by the regulators or not. Accel 75ppm, Accel 50ppm and Carbaryl 0.2% significantly ($P< 0.05$) increased the mean weights of fruits in 1995 (Table 1). The rest of the treatments did not have any effect. In 1996 Accel 75ppm, Carbaryl 0.2% and Carbaryl 0.1% were the only treatments which increased the mean weights. Accel 75ppm had similar results in 'Jon-A-Red'. Carbaryl 0.1% and Carbaryl 0.2% and all concentrations of Accel increased the mean weights of 'Braeburn' (Table 2).

Total soluble solids (Degree Brix) and pH

The bioregulators either significantly ($P< 0.05$) increased the total soluble solids or not in 1995. Carbaryl 0.2% and Carbaryl 0.1% significantly ($P< 0.05$) increased the soluble solids content in 1995 and 1996 of all apple cultivars except 'Braeburn' (Tables 1 and 2). Carbaryl 0.05% and Accel 75ppm were the only treatments, which increased the pH of 'Empire' and 'Jon-A-Red'. The pH of 'Braeburn' was not affected by any treatment in 1995 and 1996 while it was reduced by Carbaryl 0.05% in 'Empire'. All the other bioregulator treatments had no effect on pH in 1996 (Table 2): only Accel 75ppm increased the pH of 'Jon-A-Red' while Carbaryl 0.1%, Accel 50ppm and Accel 75ppm significantly ($P< 0.05$) increased the pH of 'Braeburn' (Tables 1 and 2).

Percent red color

Percent fruit red color was determined only in 1995. The percent red color of 'Empire' was significantly increased ($P< 0.05$) by Accel and Carbaryl at all concentrations (Table 1). Carbaryl 0.05% significantly ($P< 0.05$) reduced the color of 'Jon-A-Red' while Accel did not.

4.0 DISCUSSION:

4.1 Effect of Accel and Carbaryl on Fruit Set and Yield

As the concentrations of Accel and Carbaryl increased in both experiments conducted in 1995 and 1996 there were reductions in fruit set. The magnitude of increase depended on cultivar. The reductions in fruit set can be attributed to the thinning effects of these bioregulators. Accel has been reported to effectively thin `Empire', `Delicious' and `Gala' apples at concentrations of 25ppm to 150ppm (Hull *et al,* 1995) while Carbaryl has also been observed to thin apples (Wismer and Elfving, 1995). Though the trends in fruit set reductions did not correspond to those of yields, there were generally higher yields than the controls as the concentrations of the bioregulators increased. This implies that for some bioregulators, only an optimum concentration which gives good yields and reasonable fruit set reduction is all that is required and not higher concentrations. Some treatments did not have any effect on the yield of `Empire', Jon-A-Red' and `Braeburn'. This could either be explained by the existence of some degree of thinning needed before any yield increase or by the fact that some apple cultivars need higher concentrations or lower concentrations of the bioregulators. Westwood (1993) reported that fruit thinning is done to reduce fruit set and this increases fruit size. Increasing the leaf to fruit ratio by removing some of the fruit causes the remaining fruit to be larger, but not in direct proportion to the increase in the number of leaves per fruit. Westwood (1993) reasons that this causes some yield reduction. Davis (1986) has reported that the yield of a blue berry plant is a function of factors such as flower bud number, flower number per buds, fruit number and fruit size. The assumption has been that these factors contribute almost equally to yield.

Effect of thinning on yield has been contradictory. The results of the present study support the work by Wismer *et al,* 1995 who reported increased yield from fruit thinning but differ with those of (Valenzuela, 1992) and Hull *et al,* 1995 who reported decreased yields from thinning which could have been due to the different experimental settings under which they conducted their experiment.

4.2 Effect of Accel and Carbaryl on Fruits Quality Attributes:

Mean weight:

It is believed that thinning fruits by the bioregulators leaves a few ones which thus reduces competition for the assimilates. This leads to bigger fruits. The increase in mean fruit weights from Accel 75ppm, Accel 50ppm, Carbaryl 0.1%, Carbaryl 0.2% can therefore be attributed to the increased amount of assimilates being directed to few fruits (Greene *et al,* 1990).

Total soluble solids (^{0}Brix) and pH:

Total soluble solids were either increased or not by the bioregulators. This can be explained by the thinning activities of Accel and Carbaryl which changed the leaf to fruit ratio so that there were more leaves to support fruit growth (Greene and Autio, 1989). When there is a high leaf to fruit ratio more carbohydrates are manufactured from photosynthesis hence the increase in total soluble solids. As the total soluble solids increase the content of acids is altered or lowered causing an increase in pH as observed from some treatments of the bioregulators. Where the contents of total soluble solids and pH were not affected by the concentrations of the bioregulators it may have been either too low or too high to affect the leaf to fruit ratio of the apple trees.

4.3 Fruit Length, Fruit Diameter and Fruit Length to Diameter Ratio

The above parameters were not affected by the bioregulators in 1995 and 1996 (Tables 1 and 2). The most convenient way of expressing fruit shape is by the ratio of the longitudinal length to transverse diameter of the fruit (L:D ratio). This is a non-destructive measurement of economic importance (Westwood, 1993). The ratio permits the comparison of shapes of very small fruit in early season, with large ones later on. The length to diameter ratio may be thought of as relative fruit length. The higher the value the more elongated the fruit. The factors which affect fruit shape are: vigorous rootstocks, heavy thinning or light bloom in light crop (Westwood, 1993). Bioregulators affect fruit shape differently. GA and some cytokinins elongated the fruit (Williams and Stahly, 1969); Kinetin and IAA have no effect on fruit shape but 2, 4-D decreases fruit length (Westwood, 1993). All bioregulators used in this study had no effect on the fruit lengths and diameters of `Empire', 'Braeburn' and `Jon-A-Red' hence they do not affect fruit shape.

4.4 Number Of Seeds Per Fruit

The bioregulators had no effect on the number of seeds in fruits (Table 2). A link has been established between bioregulators sprays that influence seed number and fruit storage potential (Greene *et al*, 1982 cited by Greene 1989). It has been reported that sprays containing GA_{4+7} increase seedlessness in `McIntosh' apples, which were prone to senescent breakdown (Greene *et al* 1982 cited by Greene, 1989). Other reports have indicated that bloom or postbloom sprays containing GA_3 or GA produce parthenocarpic fruit (Bangerth, 1976 cited by Greene, 1989) or with fewer seed (Greene, 1989) that are also low in Ca. Weis *et al.* cited by Greene (1989) has reported a direct and inverse relationship between fruit Ca and senêscent breakdown

(Bramlage, *et al.*, 1979 cited by Greene, 1989). It is appatent from these reports that Accel and Carbaryl do not influence seed number.

4.5 Percent Red Color

Percent red color was only measured in 1995 and it was significantly increased by Accel and Carbaryl at all concentrations in` Empire' and reduced by Carbaryl 0.05% in `Jon-A-Red'. Consumers in different parts of the world may differ in their preferences depending on local customs and main cultivars grown. In general, highly colored fruits from a normally red cultivar are often of better quality than poorly colored ones from the same tree (Westwood, 1993). Fruits take on red, blue or purple color. Color of fruit results from synthesis of anthocyanin pigment. Direct light to the fruit is needed for red color development in peach, apricot and apple (Westwood, 1993). Red pigmentation is influenced by various cultural and environmental factors such as pruning, thinning, fertilization, temperature and light. Pruning, tillage, fruit thinning, fertilizer use and pest control affect color probably directly to the extent that they influence effective leaf area, leaf to fruit ratio, carbohydrate level and the degree of fruit shading before harvest (Westwood, 1993). A close relationship has been found between leaf to fruit ratio, sugar content and red color of `Delicious' apple. Fruit with low sugar content and low leaf to fruit ratio did not color well even when exposed to optimum sunlight (Maness, 1929). Heinecke (1964) showed that the best apple color occurred when fruits and leaves were exposed to 70% full sun, while adequate color was obtained at 40-70% full sun. He reported that at below 40% full sun, fruit color was inadequate and that soluble solids were directly proportional to light exposure. Two possible explanations for the results of the present study are that the thinning activities of Accel and Carbaryl increased the total soluble solids content and leaf to fruit ratio thereby increasing the color of the fruits and that thinning reduced the number of fruits hence exposing the leaves and fruits to adequate sunlight needed for coloring of the fruits (Heinecke, 1964). Further studies are recommended to establish the cause of the increase or decrease of red color as a result of Carbaryl and Accel sprays.

5.0 CONCLUSIONS

Experiments were conducted to evaluate the effect of Accel and Carbaryl on fruit set, yield, weight, fruit color and other quality parameters in 1995 and 1996.

It can be concluded that both Accel and Carbaryl at the concentrations used for the study effectively reduced the fruit set of all the apple cultivars tested in both years, by amounts, which depended on their concentrations and the apple cultivar. Apple yields were also generally increased as the fruit set was reduced. Therefore it can be concluded that Accel and Carbaryl at the concentrations used can increase the fruit yield of 'Empire', Jon-A-Red' and 'Braeburn'.

There were inconsistencies on the effect of the treatments on the mean fruit weights in 1995 and 1996 but it can be concluded generally that the treatments that increased the mean weights in the three apple cultivars tested were: Carbaryl 0.2%, carbaryl 0.1%, Accel 50ppm and Accel 75ppm.

The pH of the fruits also varied for the two years tested, but it can be concluded that Carbaryl 0.05%, Carbaryl 0.1%, Accel 50ppm and Accel 75ppm increased the pH of the apple cultivars with Carbaryl 0.05% also reducing the pH of 'Empire'.

There were also differences in the total soluble solids (^{0}Brix) content of 'Empire' and 'Jon-A-Red' but that of 'Braeburn' was inconsistent from year to year. It can therefore be concluded that Accel and Carbaryl increase the total soluble solids contents of 'Empire' and 'Jon-A-Red'.

It can be concluded that only the percent red color of 'Empire' was increased by Accel and Carbaryl and that Carbaryl 0.05% reduced the color of 'Jon-A-Red'. In the two years tested, Accel and Carbaryl did not affect the fruit length, fruit diameter and fruit length to diameter ratio. It can be concluded that Accel and Carbaryl at the concentrations tested had no detrimental effect on fruit shape. It can be concluded that the concentrations of Accel and Carbaryl used have no effect on the seed number per fruit.

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