UNIVERSITY OF ZULULAND

THE EFFECT OF POST-HARVEST AMMONIUM SULPHATE APPLICATION, PLANTING TIME AND SUCKER SIZE ON PLANT GROWTH AND YIELD OF QUEEN PINEAPPLE, *ANANAS COMOSUS*

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DECLARATION

I declare that this thesis, for the degree of Msc (Agric.) Plant Production at the University of Zululand is my work, except where duly acknowledged and that it has never been submitted before by myself for any degree at any university.

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To God be the glory

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ABSTRACT

Queen pineapple plant mortality as well as poor growth and development are some of the major problems facing the Hluhluwe pineapple producers. Approximately 20% of the plants do not produce fruit, due to mortality or poor growth. Queen pineapple plantings are currently established from suckers taken from harvested plants. The speed and development of suckers on the mother plant is not rapid enough to be used as planting material at fruit harvest. Therefore, suckers are left to grow on the mother plant for 6 to 8 months after harvesting the plant crop for the suckers to attain a suitable size for planting. The aim of the study was to determine, under field conditions, the effects and interactions of post-harvest ammonium sulphate fertilizer application and the duration of sucker growth on the production and quality of suckers as well as on the growth and development of subsequent plantings.

Post-harvest $(NH_4)_2SO_4$ application had a significant influence on the percentage increase in sucker fresh mass and length when interacting with the duration of sucker growth on the mother plant. Growing suckers on the mother plant for up to 8 months, after the application of post-harvest $(NH_4)_2SO_{4,}$ produced more plantable suckers than growing them for 6 or 10 months. Four sucker sizes were produced namely, size 2, 3, 4 and 5. Grading suckers by length produced more plantable material than grading by fresh mass.

Plant gain in fresh mass and stem diameter, was positively correlated with sucker size and post-harvest $(NH_4)_2SO_4$ application. At 2 months after planting, 6 symptoms that could lead to plant mortality were identified namely, wilted plants, plants toppling over, plants planted doo deep, plants growing slowly, plants with funnel rot and plant that dying back. The total percentage of these plant mortality symptoms was 19.6% in the March planting, 26% in the May planting and 33.1% in the August planting. Wilted plants and plants planted too deeply formed a greater proportion of the plants affected by the mortality symptoms in all the plantings. Some of the plants affected by the mortality symptoms recovered and grew into healthy plants, whereas some grew slowly and some died.

Sucker size and post-harvest $(NH_4)_2SO_4$ application had no significant effect on levels of mealybug, *Dymicoccus brevipes* and red mite, *Dolichotetranychus floridanus* infestation.

Post-harvest $(NH_4)_2SO_4$ application influenced the percentage of P and K in leaves in the May and August planting. Sucker size had an influence on N percentage in the March planting only. Plants established from smaller sucker sizes had a significantly higher N percentage than plants established from bigger sucker sizes.

Sucker size had an influence on flowering failure. Plants established from a smaller sucker size had a higher percentage of flowering failure than the plants established from a bigger sucker size. The March planting had a higher percentage of plants that failed to produce flowers after flower induction than the May and August planting. The total percentage of plants that failed to flower in the March planting was 15.92% (7.39% due to plant mortality symptoms and 8.53% due to unknown causes), in the May planting it was 6.02% (4.69% due to plant mortality symptoms and 1.33% due to unknown causes) and in the August planting it was 7.56% (5.39% due to plant mortality symptoms and 2.17% due to unknown causes). Plant mortality symptoms were the main cause of flowering failure in the May and August plantings. Post-harvest $(NH_4)_2SO_4$ application had a significant effect on wilted plants in the March planting and on natural flowering in the August planting. Flowering failure resulted in fruit yield loss.

Fruit yield was more influenced by the sucker size than by post-harvest $(NH_4)_2SO_4$ application. There was a positive correlation between sucker size and fruit yield. Fruit size was used to determine the influence of post-harvest $(NH_4)_2SO_4$ application and sucker size on the external and internal quality of the fruit. Post-harvest $(NH_4)_2SO_4$ application had a significant influence on fruit length, inter-fruitlet cracks, winter speckle occurrence and total soluble solids. Sucker size was found to have an influence on the number of fruitlet spirals, fruit length, crown fresh mass, fruitlet cracks, winter speckle occurrence and total soluble solids. Black spot, nectary duct and internal browning infestation were influenced by the number of days the fruit were kept in storage after harvesting. Post-harvest $(NH_4)_2SO_4$ application and sucker size had no significant influence on black spot, nectary duct and internal browning infestation.

Eight months after fruit harvest in the March and May planting, evaluation was done to determine the effect of post-harvest $(NH_4)_2SO_4$ application, sucker size and mortality symptoms on sucker yield. Plants established from bigger suckers produced longer and heavier suckers as well as a higher number of plantable suckers than plants established from smaller suckers. Healthy plants produced longer and heavier suckers as well as a higher number of plantable suckers than plants that were affected by the mortality symptoms.

Plants treated with post-harvest $(NH_4)_2SO_4$ produced quality planting material in terms of fresh mass and length. Leaving the suckers to grow for 8 months after fruit harvest produces more plantable material. Planting the planting material obtained from plants treated with post-harvest $(NH_4)_2SO_4$ increased fruit yield and profit.

Keywords: Ananas comosus, planting material quality, plant growth and mortality, flowering, fruit and sucker yield

CHAPTER 1

1.1 GENERAL INTRODUCTION

Pineapple, botanically known as *Ananas comosus,* is the leading edible member of the family Bromeliaceae that embraces about 2000 species (Morton, 1987). It is the third most important tropical fruit in world production after banana and citrus. The major pineapple products of international trade are canned slices, chunks, crush, juice and fresh fruit (Bartholomew et al., 2003).

The pineapple was brought to South Africa in 1655, but was first grown in KwaZulu-Natal in 1860 and was introduced to the Grahamstown area a few years later (Rabie, 2001). Today, the two major pineapple producing areas in South Africa are Northern KwaZulu-Natal (Hluhluwe) and the Eastern Cape (Rabie, 2001). South Africa produces 1% of the total world production. Three cultivars, Queen, Cayenne, and to a lesser extent the MD2, are cultivated in South Africa (Rabie, 2005). Much variation occurs in the types within each cultivar (Morton, 1987) (Table 1.1).

In addition to its export value, pineapple production in South Africa is very labour intensive and provides employment to many households. It is, therefore important to develop ways to improve the pineapple yield and quality in order to sustain the pineapple industry (Rabie, 2008).

Pineapple yield is dependent on the quality of the planting material, soil preparation, nutrient management and crop protection amongst many other things. A good plant establishment is a pre-requisite for a good yield (Py et al., 1987). In Hluhluwe, plant mortality as well as poor growth and development of the Queen pineapple are some of the major problems facing pineapple producers. Outcomes from discussions with pineapple farmers in Hluhluwe indicate that all the farmers struggle with the same problem of plant mortality and poor development, although they do not really know the extent of the problem. Whilst the Queen pineapple is planted at a density of 100 000 – 130 000 plants per hectare, the percentage of fruit harvested by most of the farmers is much less than expected at these populations and ranges from 72 to 78% fruit per hectare. Reject fruit (fruit that is too small, damaged or with disease symptoms) contributes 3 to 5% of the loss (Rabie, 2008). Approximately 20% of the plants do not produce fruit due to death or poor growth. The causes of poor growth are not clear, but the plants die back or develop very slowly after planting, ending up being too small to produce fruit at the time of flower induction with consequent yield reduction and lower returns to farmers (Rabie, personal communication). Reducing the causes of poor growth will enhance pineapple yield.

Table 1.1 Main characteristics of the three pineapple groups produced in South Africa

	Queen	Cayenne	MD-2
Planting material	Suckers	Mainly crowns/suckers(if sent to fresh market)	Suckers/ crowns
Planting density	100 000 - 130 000	45 000 – 60 000	60 000 – 70 000
Crop cycle (Plant to harvest)	15 – 18 months	18 -24 months	15 -18 months (grow vigorously than Queen and Cayenne)
Flower induction to harvest (days)	118 - 135	180 - 220	135 -150
Leaves	Spiny	No spines except for leaf tip	No spines except for leaf tip
Penducle	Short	Long	Shorter than Queen and Cayenne
Natural induction	More tolerant than MD2	Susceptible to natural induction	Highly susceptible to natural induction
Fruit:			
- Size	Small fruit max 1.5 kg	Large fruit 3 - 4 kg	Smaller than cayenne, larger than queen 1.5 - 2.5 kg
- Shape	Conical	Cylindrical–conical	Square shoulder
- Skin colour	Bright yellow	Pale yellow	Bright yellow
Flesh:			
- Flavour	Very sweet, less acid	Sweet and acid	Sweeter than cayenne
- Fibre	High in fibre and firm	Juicy and non-fibrous	Moderate flesh fibre
- Bruising	Does not bruise easily	Bruises easy	Bruises easily
- Shelf life	Moderate shelf life (14 days)	Moderate shelf life	Extremely long shelf life
Nematodes	Very susceptible	Very susceptible	Tolerant to *Rotylenchulus, reniformis* and *Pratylenchus brachyurus*
Disease resistance	Tolerant to *Phytophthora* Highly susceptible to Black spot	Susceptible to *Phytophthora* Less susceptible to Black spot	Very susceptible to *Phytophthora* Resistant/ tolerant to black spot

Adapted according to Morton (1987).

Selection of quality planting material is the most important factor that affects plant growth. Currently, Queen pineapple plantings are established from suckers taken from harvested plants. The suckers are left to grow on the mother plant for 6 to 8 months after harvesting the plant crop. Fertilizer (mainly N) can be applied after harvesting to promote sucker development. At planting, suckers are selected and sorted according to their size (mostly length) into 3 to 4 sizes i.e. number 1 (biggest), 2, 3 and 4. Due to the fact that the stem acts as a storage organ, especially during periods after a development phase such as shoot development, stem diameter can also influence growth (Py et al., 1987). The rate of sucker growth and development is also a function of variety and plant vigour. The plant's mass at the time of flower induction and its nutritional status are expected to have an influence on the number of suckers produced. For example, larger plants in a population tend to develop suckers early during fruit development, while in smaller plants sucker development may be significantly delayed (Bartholomew et al., 2003).

It is suspected that the high plant mortality during the crop establishment phase is linked to either poor quality of the planting material or poor growing conditions such as moisture availability and soil fertility. The emphasis of this study, therefore, on the effect of planting material quality and age on plant establishment and yield in Queen pineapples.

1.2 Hypothesis

The duration of growth of planting material on the mother plant, post-harvest ammonium sulphate $(NH_4)_2SO_4$ application and sucker size have an effect on plant growth and yield of the Queen pineapple.

1.3 Objectives

The aim of this study was to determine the effect of post-harvest $(NH_4)_2SO_4$ application on sucker development and the time required to grow suckers on the mother plant to produce quality planting material, as well as the possible effect on growth and yield of subsequent plantings. The major research question for the study was as follows:

- Does post-harvest $(NH_4)_2SO_4$ application have an effect on the quality and quantity of planting material and subsequent growth and yield of Queen pineapple?

- Is the duration of sucker growth on the mother plant (time after post-harvest $(NH_4)_2SO_4$ application) having an effect on the quantity and quality of planting material and subsequent growth and yield of Queen pineapple?
- Do sucker sizes have an effect on the quality of planting material and yield of Queen pineapple?

CHAPTER 2

2.1 LITERATURE REVIEW

2.1.1 Pineapple production for the fresh market in South Africa

The pineapple is grown for its edible fruit. In South Africa, the Queen cultivar is mainly produced in Hluhluwe in Northern KwaZulu-Natal for the fresh market, while the Cayenne cultivar is produced in the Eastern Cape for production of canned fruit. The Queen cultivar has high sugar content and has no canning qualities (Rabie, 2005).

About 700 ha of Queen pineapples are harvested each year and yield can vary between 50 and 75 tons per hectare. From 85% to 90% of the marketable Queen pineapple produced in Hluhluwe are for the South African fresh market (Rabie, 2001). The rest is either exported by air (the smaller sizes) or processed in a ready-to-eat product (10 to 15%), while most of the reject fruit (too small or blemished) is processed as dried fruit. Pineapples are sold in a ±9 kg box on the local market. The pineapples are sorted according to size, and fruit of the same size and colour are packed in a box. Fruit sizes vary from 6 (1.5 kg) to 16 (600 g) pineapples in a box. The total annual tonnage is 45 000 tons (Rabie, 2013).

Pineapples are transported by truck from Hluhluwe to most of the local markets across the country. Some farmers market directly to the larger chain stores and some pineapples are sold to factories that produce a ready-to eat product, especially for the export market (Rabie, 2005).

Pineapple exports are by airfreight and therefore, only the smaller pineapples are exported i.e. pineapples weighing between 250 and 600 g. Export pineapples are packed in a 4 kg box and also sorted by size and colour. There are 6 (600 g) to 14 (250 g) pineapples in a box. The smaller pineapples are used only for decorative purposes in hotels, guesthouses, etc. (Rabie, 2005).

2.1.2 The morphology of the pineapple plant

The pineapple is a herbaceous, perennial, self-sterile monocotyledonous plant. The cultivated pineapple *Ananas comosus* belongs to the subfamily Bromelioideae (Bartholomew et al., 2003). The genus *Ananas* is one of the largest genera in the Bromeliaceae family. The pineapple plant reproduces vegetatively from suckers, slips and crown (Py et al., 1987).

The adult plant comprises the following parts:

- The adventitious roots, which are underground.
- The stem, forming the central axis of the plant, is completely concealed by leaves.
- The leaves, which are arranged in a spiral around the stem. The number of leaves depends on the growth stage of the plant.
- The peduncle, which has bracts and bears a compound fruit or syncarp with a crown at the top.
- The shoots, which take different forms, develop from auxiliary buds and their development depends on ecological conditions (Py et al., 1987). There are 3 different types of shoots, which are used as planting material in pineapple production:

(i) The suckers, which develop on the aerial portion of the stem or more rarely underground.

(ii) The slips, which develop in the axils of the bracts on the peduncle. Slips have shorter stems and leaves and a larger rosette of leaves than suckers. The development of slips that are still attached to the mother plant is limited and is arrested as the fruit approaches maturity. Suckers continue to develop on the mother plant until they are harvested.

(iii) The crown, although it is formed by the terminal meristem, can be considered as a shoot since it can be removed from the mother plant and replanted (Py et al., 1987).

- The inflorescence of the pineapple consists of a fused cluster of sessile flowers (florets) arranged in spirals around an axis or central cylinder, which is simply an extension of the peduncle. Most of the floral tissue and the central cylinder turn fleshy and become edible. The axis of the inflorescence forms the core of the fruit (Py et al., 1987).

2.1.3 Morphological properties specific to the Queen pineapple

Queen plants are small and compact. Leaves are dark green, long and narrow with a reddish strip and many red spines at the edges of the leaf. The leaf tapers in the apical region. A mature plant has 45 to 60 leaves. The crown is small to medium, compact with many small green leaves that have a narrow red strip and numerous red spines at the edges. The plant produces numerous suckers (Brown, 1953).

2.1.4 Queen pineapple cultivation

Queen pineapples grow equally well in light sandy soils with a clay content of 6 to 10% and in heavy soils with a clay content of 25 to 35% (Kruger et al., 1997/98). The preferred soil pH is 4.5 to 5.5 (Py et al., 1987). The seedbed should be prepared to a fine tilth for effective plant rooting. It is planted on ridges, which are made after discing, ploughing and deep ripping. The ridges serve to improve drainage and aeration. Any pre-plant fertilizers, according to soil analysis, as well as pre-plant pest and disease control, are applied to the ridge, after which the ridges are covered with black polyethylene sheeting. This has an advantage of conserving moisture in the root zone, increasing soil temperature and controlling weeds. In sandy soils, plants are planted by pushing them through the plastic into the soil, but in clayey soils, a sharp tool is used to make a hole through the plastic and in the soil (Py et al., 1987).

Various parts of pineapples are used as planting material depending on the cultivar. In the case of the Queen cultivar, only the suckers and slips are used as planting material because the fruit is sold with the crown. Sucker selection and sorting require a great deal of labour (Py et al., 1987). Pineapple planting is done by hand to obtain uniform plantations. The Queen pineapple is planted on ridges with 4 to 6 plant rows per ridge in sandy soils and 3 to 4 plant rows in heavy soils. On average the ridge is 150 cm in width (centre to centre) with a 90 cm flat bed on top of the ridge and a 60cm path. Spacing between plants in the row can vary between 20 and 30 cm, giving a plant population of between 90 000 and 120 000 per hectare (Cassidy and van Wyk, 1998).

Plants in sandy soil grow faster than those in heavy soils, and all the production practices have to be done quicker. Nematode populations in sandy soils increase at a faster rate than in heavy soils causing severe root damage. This has a negative impact on plant nutrient uptake, especially during the critical phase of the fruit development, and therefore fruit quality is reduced (Kruger et al., 1997/98).

Pineapples in Hluhluwe are produced all year round under dry land conditions (Rabie, 2005). To achieve the year-round production, suckers of different sizes are planted at different times of the year, followed by the use of the flower induction (forcing) agent, such as ethephon [(2-chloroethyl) phosphonic acid], which play a significant role in managing harvesting activities. With the use of artificial flower induction, the pineapple can bear fruit at any time of the year. The advantages of forcing are to initiate flowering, shorten crop cycle and increase yield. It also ensures uniform, complete and concentrated harvesting (Py et al., 1987).

For proper planning, it is, therefore, important to know the duration of the different vegetative stages as well as the length of the flowering and fruit ripening stages. Depending on planting time and sucker size, the vegetative stage can be from 8 to 12 months. Flower induction will then take place and the length of the different flowering stages will again vary according to the season. The time of flower induction is determined by the plant size. There is a positive correlation between plant size and fruit size, and it is therefore better to induce a larger plant if larger fruit are needed. The time from flower induction to first flower (i.e. when the inflorescence can first be seen in the heart of the plant) can vary from 5 to 9 weeks. It first appears as a light coloured plateau at the bottom of the enlarging rosette of leaves. Following this stage is the red heart (short peduncle) to red bud (long peduncle) stage, which lasts 1 to 2 weeks. The true flowering stage (blue flower stage) appears after the red bud stage when each floret develops in a purple coloured flower opening from the bottom of the inflorescence to the top in a spiral (Py et al., 1987). This period lasts for 2 to 4 weeks depending on the season (Rabie, 2005).

At the end of the blue flower stage, all the flower petals will be dead (100% dead petal stage) and the fruit then starts to enlarge (Rabie, 2005). The florets then develop into fruitlets. The period from dead petal stage to harvest is 3 to 4 months. In total, the period from flower induction to harvest can vary from 5 to 8 months (Rabie, 2005).

A fruit enlarger (2-(-chlorophenoxy) propionic acid / Swelpine) is applied after 100% dead petal stage to increase fruit size and reduce top size. When the total soluble solids (TSS; indicates sugar content)) of the fruit is above 12 ^{o}Brix, ethepon is applied. Ethepon is registered for two specific uses in pineapple production: for flower induction and to change the colour of the skin for uniform colouring at maturity (de-greening) (Loeillet and Paqui, 2010). Since the pineapple is a non-climacteric fruit, it should be harvested when ready to eat. Harvesting should be done 7 to 14 days after yellowing and care should be taken that the fruit is not too green or too ripe, not bruised or damaged and that it is not affected to a large extent by any physiological problems (Cassidy and van Wyk, 1998). The complete crop production cycle can take 12 to 18 months (Rabie et al., 1998; 1999).

The field is still maintained for another 6 to 8 months after harvesting to allow the suckers to develop for planting material. The plants will then be lifted; the suckers removed from the mother plant and sorted into sizes. After removal of the planting material to the new fields, the plant rests will be incorporated in the soil and the field rested for 2 to 3 years (Rabie, 2005).

2.1.5 Influence of climate on growth of Queen Pineapple

Hluhluwe is a summer rainfall area (September to April), receiving an average of 650 mm rain/annum. The Hluhluwe pineapple plantations are not irrigated. In prolonged dry spells, the plants obtain their moisture from condensation of mist from the large water body in the area (Kruger et al., 1997/98). Since the pineapple plant has a crassulacean acid metabolism (Py et al., 1987) it can utilize minimum rainwater and even dew effectively. Water or dew will collect in the funnel of the plant where it will be absorbed by the leaves. Excess water will run down against the stem and directly to the plant base for absorption by the roots (Cassidy and van Wyk, 1998).

The average temperature for the summer (23.3 ^{o}C) and winter (18.9 ^{o}C) is within the optimum temperature range for pineapple growing which is 15 to 32 ^{o}C (Rabie, 2005). Growth is limited during the dryer and colder winter months. Leaf formation slows down to 1 leaf per month, while it increases to 4 to 5 leaves per month during the warm and wetter summer months. Therefore, planting of pineapples is stopped during May and starts again at the end of July. Fields planted in May are often harvested at the same time as those planted at the end of July/beginning of August. Manipulation of these plantings is done by planting different plant sizes (Rabie, 2005).

Temperature and day length also influence flower induction. Natural flower induction occurs under low minimum temperatures and short days. Depending on the time of planting, plant sizes 2 and 3 are susceptible to natural flowering (Rabie et al., 2010).

2.1.6 Sucker development

The Queen pineapple is produced for sale as a fresh fruit complete with its crown. As the Queen plant cultivated in South Africa does not produce slips, the only planting material available is suckers, and their production is therefore indispensable. The speed and development of shoots on the mother plant depends on the cultivar, pests, disease, and on the environmental conditions, especially climate, but in general even the fastest growing sucker cannot grow rapidly enough to be used as planting material at fruit harvest. Sucker development must continue on the mother plant until suckers are big enough to be used as planting material. A third phase, namely the sucker development stage, can therefore be added to the 2 main development stages, namely the vegetative and fruit development stages. Proper care is very important during this stage as it determines the quality (vigour) of the future planting material and therefore the future crop. It also partially determines the health condition (pest and disease infestation) of the plot at planting (Py et al., 1987). Fertilizer application for sucker development after harvest in Queen pineapple cultivation is often not a common practice (Rabie, 2008).

To obtain satisfactory sucker production, care should be taken that plants of the plant crop have a healthy root system to ensure adequate mineral nutrition, so that root activity can continue satisfactorily after fruit harvest. Practices to be considered are weed control, ants and mealybug control, nematode control and fertilizer application (Py et al., 1987).

It is important to know the period needed for suckers to reach the required size and to know when vigour starts to decline as the mother plant becomes too old (Py et al., 1987). Little is known about the effect of the age of planting material (Rabie, 2008).

2.1.7 Selection of the planting material

Grading of the planting material is very important as the development of the plants depends on the material planted. Uniform planting material results in uniform growth of the plants, enabling uniform farm operations (Py et al., 1987). The higher the density to be planted, the stricter the grading should be (Py et al., 1987). When grading the planting material, sanitary conditions should be monitored. Any planting material with visible signs of pest and disease infestation, and physical damage should be eliminated (Py et al., 1987).

Suckers selected as planting material should not have roots less than 5 cm; those with roots longer than 5 cm (so-called bearded suckers) are more likely to have initiated flowering (Cassidy and van Wyk, 1998). Immature suckers which are characterized by firm and straight leaves should be discarded (Cassidy and van Wyk, 1998). The 5 important characteristics to be considered by the growers when selecting the pineapple planting material are vigour, disease resistance, uniformity, fruit characteristics and production of sufficient planting material (Brown, 1995).

2.1.8 Fertilizer management

Fertilization is one of the important production aspects that is easy to control in order to increase the profitability of the pineapple crop. It is crucial not to isolate fertilization from the whole range of plant-soil-climate cultivation techniques, since climate regulates the response of a crop to fertilization (Py et al., 1987). The 2 main pineapple crop fertilization factors to be considered are the plant’s root absorption capacity and the plant’s morphology, which favours leaf absorption allowing the application of foliar nutrition (Py et al., 1987).

A correct fertilizer programme for each land area is determined by a chemical soil analysis. A soil sample should be taken about 6 months prior to the planting date. The soil is analysed to determine pH, the nutritional status of the soil and the fertilizer programme to be applied, while soil texture is analysed to determine the quantity and form of lime required. When lime is required, it must be applied and ploughed in at least 3 months before planting. If leaf analysis is required to determine the nutritional status of the plant, it should be done between 4 and 6 months after planting so that the necessary fertilizer applications can be made to the crop before flower induction. A sample of 10 D-leaves per land area or treatment is used for leaf analysis (CSFRI, 1986). The D-leaf represents an easily identified standard leaf that is commonly used to index growth and evaluate plant nutrient status. The level of nutrients in the D-leaf represents the amount of nutrients currently absorbed by the plant (Ramos, 2006).

The pineapple is a shallow feeder with a high requirement for nitrogen and potassium. These can be applied in the form of a complete fertilizer mix to the soil or onto the lower leaves of the plant taking care to avoid the heart of the plant or burning may result (CSFRI, 1986).

Because of leaching, nitrogen should be applied in split dosages of pre- and post-plant application to fulfil the plant's requirements throughout the crop cycle. In Hluhluwe, the post-plant nitrogen is applied 2 to 3 months after planting at a rate of 1000 kg/ha of $(NH_4)_2SO_4$ applied by hand on the soil at the side of the plant. During the cold season and drought when plant growth is slow, the application is split into 2 equal halves. Urea is applied as a foliar spray at flower differentiation (CSFRI, 1986). Potassium is applied before planting and should be enough for the complete crop cycle, but if leaf analysis results show it is deficient, it can be applied as a foliar spray of potassium sulphate or potassium nitrate at 4% concentration (CSFRI, 1986).Potassium is the nutrient that accumulates in the largest amount in the plant. It influences productivity although to a lesser extent than nitrogen. The large demand of K often results in symptoms of potassium deficiency (Py et al., 1987).

Phosphorus is not readily leached from the soil, and the total requirement for the crop cycle can be applied once, as the base fertilizer at planting (Kelly and Bartholomew, 1993). Phosphorus in pineapple plants is relatively in small demand, but increases in productivity have been recorded (Py et al., 1987).
Pineapple plants receiving N,P and K produce higher yields of best quality fruits (Obiefuna et al., 1987).

During the cold season and drought when plant growth slows down or stops, fertilization should be reduced accordingly. The micro elements Zn, Cu, Fe, and B should be applied when leaf analysis results show deficiency levels. They can be applied by foliar spray at 2000 l H_2O/ha (CSFRI, 1986).

2.1.9 Weed control

The development of the pineapple crop is strongly negatively affected by the presence of weeds (de Matos et al., 2009). Weed control in pineapple plantations Hluhluwe is done by herbicide spraying and hand hoeing. The number of interventions for weed control during the crop cycle depends on the weed population. Due to the long cycle of the pineapple, herbicides with a long residual period can be used (Poffley and McMahon, 2006). Although there are a number of herbicides recommended for pineapple, they all have limitations with regard to lack of sufficient weed control, phytotoxicity or excessive quantity of water per hectare for each application. Total weed control cannot be obtained from a single product. The best method to obtain optimum weed control is by applying a combination of herbicides (Murray and Hoffman, 2000).

2.1.10 Pineapple pests and disease

The common pineapple pests in Hluhluwe are nematodes, mealybugs and red mite. Internal quality problems of fruit are caused by black spot and nectary duct infection as well as internal browning, while the external quality problems are winter speckle and inter-fruitlet cracking (Rabie, 2005).

Nematodes

Among the pests, plant parasitic nematodes are the most important source of losses in pineapple production. In northern KwaZulu-Natal, *Pratylenchus brachyurus* and to a lesser extent *Meloidogyne javanica* are of economic importance in the cultivation of Queen pineapple (Rabie, 2008). Nematode infestation can be seen by symptoms of discoloration or patches of stressed plants even under satisfactory climatic and agronomic conditions. Sampling is required to identify the nematode species involved (Luc et al., 1990). A representative sample should comprise sick as well as healthy plants to avoid drawing wrong conclusions with regard to the nematode population (Daneel et al., 1994).

Nematodes can be controlled by the application of pre-plant and/or post-plant nematicide treatments. Nematicides comprise the largest (by mass) category of pesticide used in the pineapple cropping system. Farming practices such as clean fallow period, crop rotation and application of soil amendments can be practiced to suppress nematode populations (Rabie, 2008).

Mealybug and red mite

Hluhluwe pineapple farmers do not dip their planting material into pesticides before planting. As a result, the mealybug, *Dysmicoccus brevipes* and red mite, *Dolichotetranychus floridanus* become important a few months after planting (Petty and Webster, 1981).

Mealybug is a vector of mealybug wilt diseases. It is tended and protected by ants (a number of species are involved) which tend and feed on its honey dew (Duodu and Thompson, 1992). Mealybugs are found at the base of the leaves and fruit covered by a white waxy deposit (Poffley and McMahon, 2006). Mealybugs can be controlled indirectly by controlling the ants which carry immature mealybugs from infested to uninfested plants. The direct control method is by spraying a chemical on the plants at high volume for the liquid to reach in the lower leaf axils where mealybugs like to hide (Petty, 1978). There are registered chemicals for the control of ants and mealybugs.

Py et al., (1987) describes *Dolichotetranychus floridanus* as being 0.2 mm in length and 0.07 mm in width, reddish orange in colour and generally found at the base of the oldest leaves forming colonies. They can also be found in the crown. Their presence on the leaves can be identified by areas of necrosis which are brown. However, there is disagreement on the economic significance of red mites.

Black spot

Black spot has been known since 1896. This fungal disease occurs in all pineapple producing areas of the world and it was first reported in South Africa in 1924. Black spot is a development of dark, necrotic tissue internally around the seed cavity and nectary ducts. It is an infection of the fruitlets with *Penicillium funiculosum* and/or *Fusarium moniliforme*. There are 2 types of black spot known in South Africa: wet spot and dry spot. Wet spot is characterized by a soft and watery tissue, and in dry spot the infected tissue becomes brown and corky (Rabie, 2000/2001). Fruit infected before maturity develops dry spot and fruit infected when matured under humid conditions develops wet spot (Glen-Leary, 1992).

Three factors are thought to be responsible for the black spot infection in pineapple fruits (CSFRI., 1991). The first is the feeding activity of insects such as mealybug, thrips and mites in the floral cavity. The second is the lignification and suberisation of floral cavity and nectary ducts, which may produce an uneven stretching of tissue during ripening. The third is moisture and temperature variations that produce uneven stresses in the tissue and result in cracking of epidermal tissue. The above-mentioned factors cause ports of entry for the pathogens (CSFRI, 1991). Wound infection can occur at any stage of fruit development. The development of black spot is insignificant when the fruit is still green, but it progresses rapidly as the fruit ripens. Black spot disease has negative effects on the fruit quality and shelf life (Py et al., 1987). Low calcium and magnesium favour black spot disease infection and larger fruit are more susceptible to the disease than smaller fruits (Rabie, 2000/2001). Black spot can be controlled by applying fungicides to control the fungi which are the primary causal organisms and also by controlling the insects feeding in the floral cavity (CSFRI, 1991).

Internal browning

Internal browning is a physiological darkening of the tissue around the fruit core after storage. This disorder is caused by the mobilization of K^+ ions from the core to the crown of the pineapple fruit when stored between temperatures of 10 ^oC to ±2 ^oC and a relative humidity of 85 to 95% for more than 7 days (Nanayakkara et al., 2005). The problem is identified by a small slightly brown spot around the core, which gradually becomes dark brown and advances until the entire core and surrounding tissue are affected. The disorder can be eliminated by harvesting physiologically mature fruit and reducing the storage time of the fruit by rapid transportation to the consumers (Nanayakkara et al., 2005).

Winter speckle

Winter speckle is a disorder that occurs on the fruit skin, but does not affect the fruit quality. It occurs as a circle of reddish brown corked tissue around the flower opening of the fruitlet. This corking can vary from slightly corked to a solid ring of corked tissue. It can be on a few fruitlets, but in severe cases it can cover the whole fruit (Rabie, 2003/2004). So far, the major cause of the problem has not been found (Rabie and Tustin, 2006).

Inter-fruitlet cracking

Inter-fruitlet cracking is the appearance of cracks in the tissue between fruitlets. These cracks are commonly found on the lower part of the fruit near the peduncle and they can appear at any time of the year. They are a result of fruit growth and may be induced by rapid changes in weather such as temperature and humidity (CSFRI, 1991). In most cases fruit quality is not affected by inter-fruitlet cracking but there are rare cases where it leads to a condition known as inter-fruitlet corky streak, and the affected fruit is rejected in the market. The factors leading to inter-fruitlet corky streak are not known (CSFRI, 1991).

CHAPTER 3

EXPERIMENT 1.THE EFFECT OF POST-HARVEST FERTILIZER APPLICATION ON SUCKER DEVELOPMENT OF THE QUEEN PINEAPPLE, *Ananas comosus*

3.1 INTRODUCTION

Approximately 700 ha of Queen pineapple are harvested each year by the pineapple growers of Hluhluwe. The yield per hectare can vary from 50 to 75 tons. The Queen cultivar is mainly produced for the fresh market. The area under Queen pineapple production is small in comparison with that of other tropical and subtropical fruit in South Africa, but pineapple production in Hluhluwe is of great socio-economic importance in that region. Apart from numerous game farms, the only other agricultural industries in Hluhluwe are sugarcane and timber production, but for both these crops, the area is classified as being marginal. Pineapple cultivation is very labour intensive and provides employment to many households. It is therefore important to develop ways to improve pineapple quality and quantity to sustain the industry (Rabie, 2008). Improving the quality of the planting material is the first step towards increasing pineapple yields as well as improving total pineapple production without increasing land area.

Currently, Queen pineapple plantings are established from suckers taken from plants after their fruit has been harvested. The suckers are left to grow on the mother plant for 6 to 8 months after the fruit has been harvested. The speed and development of shoots on the mother plant depends on the cultivar, plant nutrition and on the environmental conditions, especially climate (Bartholomew et al., 2003). Sucker development must continue on the mother plant until suckers are big enough to be used as planting material. Thus, in addition to vegetative and fruit development stages, there is a third phase in the pineapple production cycle, namely the sucker development stage. Proper care is very important during this stage as it determines the quality of the future planting material and the health condition (pest and disease infestation) of the crop at planting (Py et al., 1987). Research indicates that pineapple sucker formation is influenced by N fertilization (Py et al., 1987; Dalldorf, 1992). However, applying N fertilizer after harvest for sucker development is often not a common practice (Rabie, 2008).

Selection of quality planting material is one of the most important factors that affects pineapple plant growth. Studies have shown that the uniformity and quality of the planting material used is dependent on the grading method (Py et al., 1987). Farmers have generally experienced high mortality of plants when pineapple crops are planted just before winter. It is suspected that the high plant mortality in these plantings is linked to the poor quality of the planting material. This is a result of poor growing conditions, such as poor moisture availability or poor N fertility, during sucker growth.

Currently, little is known about the effect of the age of planting material on subsequent plant development and fruit yield (Rabie, 2008). Also, whilst the effect of N on sucker development is known (Py et al., 1987), the effect of the N application rate during sucker development on subsequent plant growth after the suckers have been planted is not known.

The present study was conducted with the aim of finding means of improving the quality and quantity of the planting material for Queen pineapple cultivation. Three hypotheses were tested namely;

(i) Post-harvest nitrogen fertilizer application improves growth and development of the suckers on the mother plant as well as plant growth in subsequent plantings.

(ii) The number of suckers and size (quality) are determined by the duration of the growth period on the mother plant.

(iii) Effective grading of suckers improves quantity and quality of the planting material.

3.2 METHODS AND MATERIALS

3.2.1 Crop plant establishment and management prior to fruiting

The experiment was conducted in KwaZulu-Natal (S 28° 0’ 50”; E 32° 16’ 30”) at Kleynfaan Estate, Hluhluwe. The soil pH was 5.6. The total rainfall was 913.15 mm, with a maximum temperature of 27.09 °C and the minimum temperaturer of 17.36 °C. The soil type was sandy soil with 6% clay content. Pineapple, cv. Queen, was planted in April 2007 at a population of 128 000 plants/ha in 2 blocks of land (hereafter referred to as KH10 and KH15), each measuring 0.5 ha. Thereafter, the plants were maintained as recommended (Cassidy and Van Wyk, 1998). Pineapples were harvested from the blocks in August 2008.

3.2.2 Nitrogen treatments

One month after fruit harvest, the trial was laid out in a randomized complete block design with 3 replicates of 0.07 ha. Each plot consisted of 3 ridges with 6 plant rows per ridge. Ammonium sulphate $(NH_4)_2SO_4$ was selected for the nitrogen treatment in this and subsequent experiments. Trials comparing $(NH_4)_2SO_4$ and urea have shown that $(NH_4)_2SO_4$ is superior to urea in improving pineapple plant growth (Py et al., 1987). It is believed that the sulphate ion in the $(NH_4)_2SO_4$ enhances the performance of the salt (Py et al., 1987). Three rates of $(NH_4)_2SO_4$ fertilizer were applied over the ridges at 4 weeks after harvest. The $(NH_4)_2SO_4$ treatments were 0 ton/ha (control), 0.5 ton/ha and 1 ton/ha to supply 0 kg, 105 kg and 210 kg of N/ha. The $(NH_4)_2SO_4$ was broadcasted over the plants using a motorbike-mounted applicator (Fig. 3.1).

Figure 3.1 Broadcasting $(NH_4)_2SO_4$ over the pineapple plants with a motorbike-mounted applicator at 4 weeks after fruit harvest.

3.2.3 Evaluation of sucker growth

Sucker development in each treatment was evaluated at 4, 6 and 8 months after $(NH_4)_2SO_4$ treatment application in block KH15 and at 2, 8 and 10 months after $(NH_4)_2SO_4$ treatment application in block KH10. Planting material for three subsequent trials (see Chapter 4) was obtained from KH15, but KH10 was also treated as a back-up in case KH15 did not produce enough planting material for the trials.

Sucker development in each N treatment was supposed to be evaluated every 2 months in both KH10 and KH15 blocks, starting 2 months after the $(NH_4)_2SO_4$ application. An initial evaluation of sucker growth at 2 months after the $(NH_4)_2SO_4$ treatment showed that suckers were too small and far from reaching the minimum plantable size in terms of both the length and mass. It was then decided to skip the KH15 evaluation but a small sample was done to confirm that suckers were too small for planting. This was to minimize the number of plants removed in the sampling process as well as reducing the time of data collection. Because fresh mass was used, it was important not to keep plants standing for too long before taking measurements. The whole process of evaluation took 4 days for each block, which means that 11 days would pass between the first and the last plant evaluated if both blocks were evaluated.

Thus, at ≥4 months after $(NH_4)_2SO_4$ application, a small sample of 10 plants per treatment was taken at random in block KH10 and KH15 for comparison. Since the results of the small sample showed no difference between the 2 blocks, complete evaluation was done in KH15 with a sample of 10 plants per replicate of each treatment taken at random. At 8 months after $(NH_4)_2SO_4$ application, growth differed in the 2 blocks and both blocks were evaluated and the results are presented. As predicted, KH15 did not produce sufficient planting material, especially of the larger sucker sizes.

In Hluhluwe suckers are graded according to fresh mass and length. Although dry mass is a more accurate method to measure plant growth, for the purpose of this trial fresh mass was used to provide practical recommendations that can be adopted by the farmers regarding sucker growth and grading. At each evaluation, 10 plants per replicate, selected at random were removed for evaluation. Suckers of each plant were removed, counted, weighed (fresh mass) and their length measured. To calculate plant fresh mass and length increases, the latest measurement was subtracted from the previous average measurement. It was noted that as the suckers got older, the old leaves, which are the longest, dried out from the tips and sometimes the dry part would break off. For this reason only the green part of the plant was measured for length. The stem length and diameter of the mother plant without suckers were also measured.

3.2.4 Grading of suckers according to sizes

Sorting suckers according to sizes for planting is an integral part of pineapple farming and this task is usually done by a special team. As already mentioned, grading of suckers is often done according to the length of the suckers, although sucker mass is also an important criterion. However, sorting according to mass is thought to be more difficult and cumbersome. A short and heavy sucker will often grow better compared to a long and thin sucker. The skill to sort/grade suckers for planting develops with experience, and the sorting/grading is done visually without the aid of a measuring tape or balance. For the purpose of this study, suckers in each treatment were sorted into 4 different categories by an experienced team after which the length, mass and stem diameter of 30 suckers in each size were measured. By eliminating the overlapping measurements of the different sizes, the minimum and maximum value for each criterion (length and mass) for the different sucker sizes were established. These measurements were used in determining the number of plantable suckers from each treatment (Table 3.1). In this trial the biggest suckers were discarded. These suckers had a lot of roots on the planting end and were difficult to insert and therefore toppled over easily. A high percentage of these suckers can also be naturally induced (so called “pregnant” suckers) and will bear a small fruit shortly after planting.

Table 3.1. Criteria for grading suckers into size class by fresh mass and length.

	Size class 5	Size class 4	Size class 3	Size class 2
Sucker fresh mass	124-50g	174-125g	215-175g	>215g
Sucker Length	42-30cm	52-43cm	56-53cm	>57cm

Table 3.2. shows the maximum and minimum temperatures as well as the total accumulated rainfall throughout the period of the trial from.

Table 3.2. Temperature and rainfall from August 2008 to August 2009.

		Temperature °C		
Month	Year	Mean maximum	Mean minimum	Total rain (mm)
August	2008	26.63	15.45	3
September	2008	25.94	1491	34.6
October	2008	26.8	17.86	10
November	2008	27.61	20.07	129.7
December	2008	30.16	21.13	573
January	2009	30.71	21.55	135.40
February	2009	29.39	21.50	326.80
March	2009	28.63	19.87	78.60
April	2009	27.10	17.43	45.30
May	2009	25.77	16.03	25.15
June	2009	25.14	13.91	12.00
July	2009	24.08	11.95	7.9
August	2009	24.32	14.02	47.40

A composite soil sample of KH10 to KH 15 was taken prior to planting in March 2007 (Table 3.3). The soil was sent to the laboratory and analysed using the standard method of soil analysis. Phosphorus was analysed using (Bray 1).

Table 3.3. Soil analysis results of block KH 10 to KH 15.

Block	pH (water)	Res (oms)	Ca mg/kg	Mg mg/kg	K mg/kg	Na mg/kg	P (Bray1)	Al mg/kg	Ca/Mg	Ca+Mg/K
KH 10-15	5.66	1700	157	62	44	18	9.3	37	2.53	4.98

3.2.5 Statistical analysis

A general ANOVA was conducted using Genstat twelfth edition (Genstat, 2009). Significant differences between the means was determined by LSD at the $P \leq 0.05$ probability level.

3.3. RESULTS

3.3.1 Sucker growth and development on the mother plant

Post-harvest $(NH_4)_2SO_4$ application had no significant effect on sucker fresh mass and length (data not shown), but the duration of sucker growth on the mother plant signifiantly affected sucker fresh mass and length (Table 3.4).

KH10

In Block KH10, the sucker fresh mass and length increased by 227 and 144% respectively, from 2 to 8 months after post-harvest $(NH_4)_2SO_4$ application, but from 8 to 10 months, there was a 14% and 3.5% decrease in sucker fresh mass and length respectively. The increase in sucker fresh mass and length (Table 3.4) from 2 to 8 months after post-harvest $(NH_4)_2SO_4$ application was significant ($p < 0.001$), whereas the decrease in sucker fresh mass and length that occurred from 8 to 10 months was not significant.

KH15

In block KH15, in which evaluations were done at shorter intervals, time had a significant effect on the percentage increase in sucker length (Table 3.4). Sucker length increased by 80.9% from 4 months to 6 months and by 17.8% from 6 to 8 months after post-harvest $(NH_4)_2SO_4$ application. The increase in sucker length from 4 to 6 months after post-harvest $(NH_4)_2SO_4$ application was significantly higher ($p < 0.001$) than the increase in sucker length that occurred from 6 to 8 months. (Table 3.4). The actual data used to calculate the percentages is presented in Appendix (Table 1 A and B).

Table 3.4. Effect of time (months) on sucker fresh mass and length.

Block KH10		Block KH15	
Time interval after post-harvest $(NH_4)_2SO_4$ application	Increase in sucker fresh mass (%)	Time interval after post-harvest $(NH_4)_2SO_4$ application	Increase in sucker fresh mass (%)
2 - 8 months	227	4 - 6 months	60.9
8 - 10 months	-14	6 - 8 months	41.4
$LSD_{0.05}$	65.1	$LSD_{0.05}$	31.8
	% sucker length increase		% sucker length increase
2 - 8 months	144.1	4 - 6 months	80.9
8 - 10 months	-3.5	6 - 8 months	17.8
$LSD_{0.05}$	27.6	$LSD_{0.05}$	22.5

3.3.2 Percentage of plantable suckers using length and fresh mass as a grading criterion

The effect of post-harvest $(NH_4)_2SO_4$ application

KH15

Post-harvest $(NH_4)_2SO_4$ application had a significant effect on the percentage of plantable suckers selected by length fresh mass (grams) (Fig. 3.2 A and B). The sucker length was strongly and positively correlated with $(NH_4)_2SO_4$ application rate (Fig. 3.2 A and B). The 1 ton and 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ application had a significantly higher ($p < 0.001$) percentage of plantable suckers, than the percentage plantable suckers in the 0 ton post-harvest $(NH_4)_2SO_4$ application treatment (Fig. 3.2 A and B).

KH10

Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the percentage of plantable suckers selected by length and fresh mass) (Fig. 3.2 A and B). However, the trend was for the sucker length to increase with increasing rate of $(NH_4)_2SO_4$ application (Fig. 3.2 A and B).

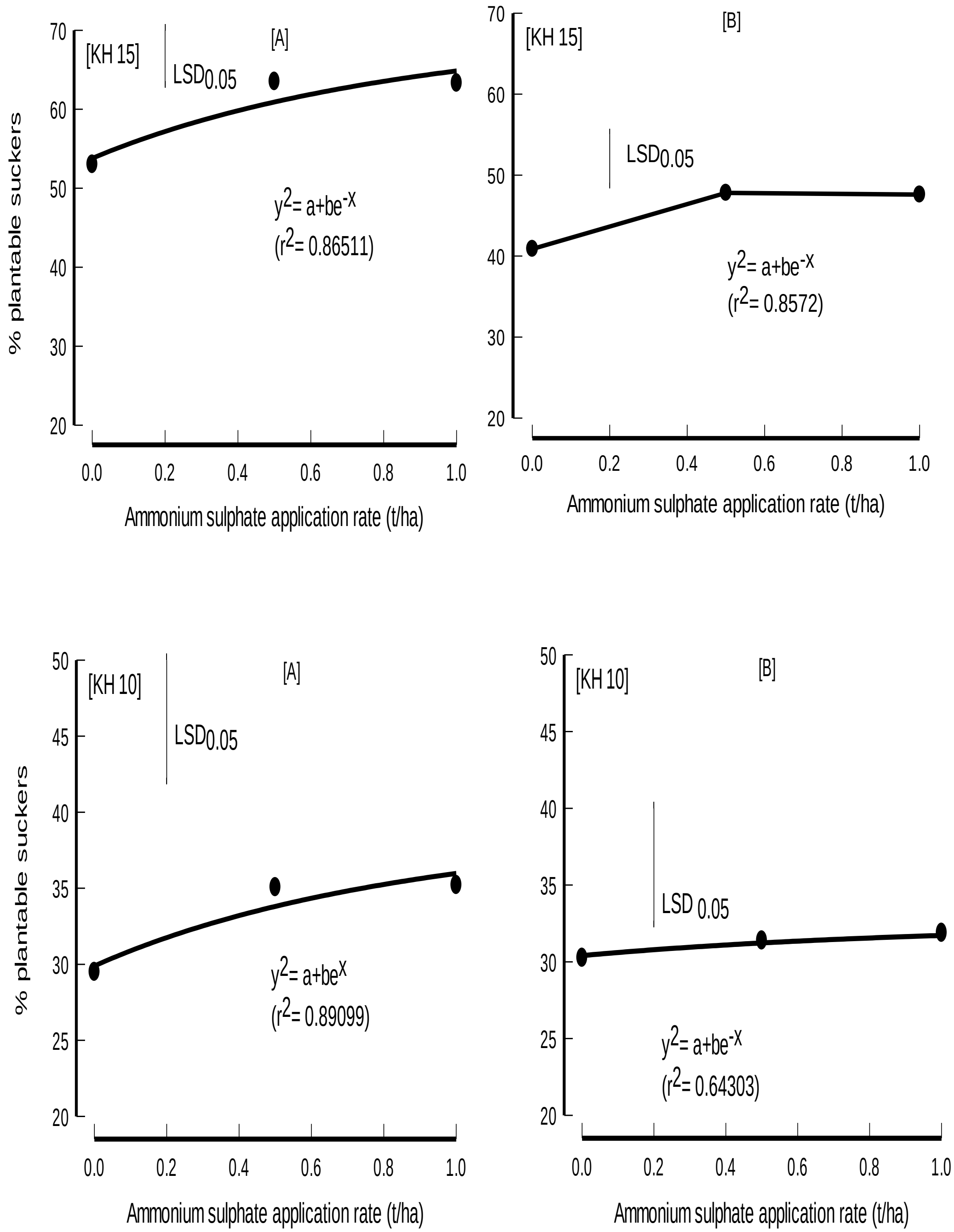


Figure 3.2. Effect of post -harvest $(NH_4)_2SO_4$ application on the percentage of plantable suckers selected by sucker length (cm) in KH15 [A] and KH 10 [A] and sucker fresh mass (g) in KH15 [B] and KH10 [B]. (Data points are means of 3 replicates).

The effect of growth duration (time in months)

KH15

The percentage of plantable suckers selected by length and fresh mass increased significantly with an increase in time (Fig. 3.3 A and B). The highest percentage plantable suckers, 81.7%, was found 8 months after post-harvest $(NH_4)_2SO_4$ application, while the lowest percentage plantable suckers, 27.7%, was found at 4 months after post-harvest $(NH_4)_2SO_4$ application (Fig. 3.3 A).

The highest percentage of plantable suckers (62.5%) was obtained at 8 months after post-harvest $(NH_4)_2SO_4$ application, while the lowest percentage of plantable suckers (27%) was at 4 months after post-harvest $(NH_4)_2SO_4$ application (Fig. 3.6 B).

KH10

Time had a significant effect on the percentage of plantable suckers selected by length and fresh mass (Fig. 3.3 A and B). The percentage plantable suckers, 50.1% and 46.8% at 8 and 10 months after post-harvest $(NH_4)_2SO_4$ application, were significantly higher ($p < 0.05$) than the percentage plantable suckers (2.8%) at 2 months after post-harvest $(NH_4)_2SO_4$ application (Fig. 3.3 A). The percentage of plantable suckers, 46.2% and 38.9% at 8 and 10 months after post-harvest $(NH_4)_2SO_4$ application respectively, were significantly higher ($p < 0.05$) than at 2 months (8.3%) after post-harvest $(NH_4)_2SO_4$ application (Fig. 3.3 B). There were more plantable suckers at 8 months than at 10 months after post-harvest $(NH_4)_2SO_4$ application, although there was no statistical difference (Fig. 3.3 A and B).

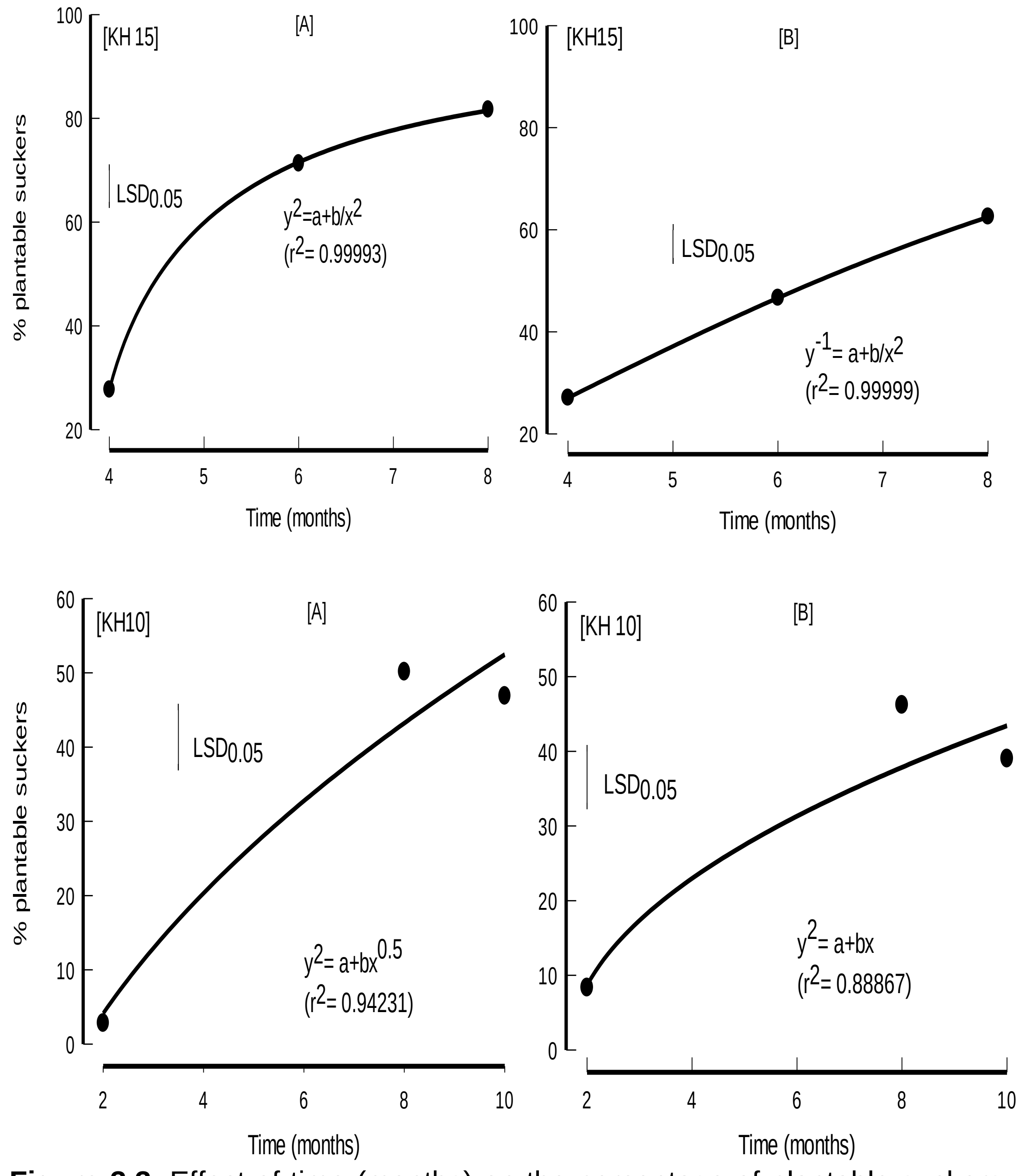


Figure 3.3. Effect of time (months) on the percentage of plantable suckers selected by sucker length (cm) in KH15 [A] and KH 10 [A] and sucker fresh mass (g) in KH15 [B] and KH10 [B]. (Data points are means of 3 replicates).

Interaction effect

KH10

There was a weak interaction between duration of sucker growth on mother plant and application of $(NH_4)_2SO_4$ on sucker sizes (Fig. 3.4). In evaluations done at 2 months in block KH10, an average of 95% of the suckers was not plantable. Of the plantable suckers only size 5, which constituted an average of 5% of the suckers, was available. The percentage of plantable suckers increased with time but the greater majority of the suckers were in the unplantable category (Fig. 3.4). At 8 and 10 months, the plantable number of suckers was reduced markedly when no $(NH_4)_2SO_4$ was applied, especially at 10 months. Plants not supplied with $(NH_4)_2SO_4$ did not produce sucker size 2 at 8 and 10 months. There was little variation in the other sucker sizes at 8 and 10 months (Fig. 3.4). The treatment that produced the highest percentage of plantable suckers namely 52%, was at 10 months in plants treated with $(NH_4)_2SO_4$ at 1 ton/ha. The lowest percentage of plantable suckers (4%) was at 2 months in the control treatment (0 ton $(NH_4)_2SO_4$ /ha) (Fig. 3.4).

KH15

There was a positive interaction effect between the duration of sucker growth on mother plant and post-harvest $(NH_4)_2SO_4$ application on the percentage and size of the suckers selected by length (Fig. 3.4). In evaluations conducted at 4 months in block KH15, an average of 72% of the suckers was not plantable. Of the plantable suckers, an average of 20% was sucker size 5. Only plants that received 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application produced a small percentage of sucker size 2 and 3 (Fig. 3.4). At 6 months, the percentage of plantable suckers was significantly higher in plants supplied with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ than when no post-harvest $(NH_4)_2SO_4$ was applied. Plants treated with post-harvest $(NH_4)_2SO_4$ had a significantly higher percentage of sucker size 2 than the plants in 0 ton/ha and 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 3.4). At 8 months there was no significant difference on the percentage of plantable suckers produced between the different post-harvest $(NH_4)_2SO_4$application rates. The difference was between the percentages of sucker sizes produced in different post-harvest $(NH_4)_2SO_4$ application rates. The percentage of sucker size 2 was significantly higher in plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_{4,}$ than when no post-harvest $(NH_4)_2SO_4$ was applied (Fig. 3.4). The highest percentage of plantable suckers was produced at 8 months, while the lowest was produced at 4 months (Fig. 3.4).

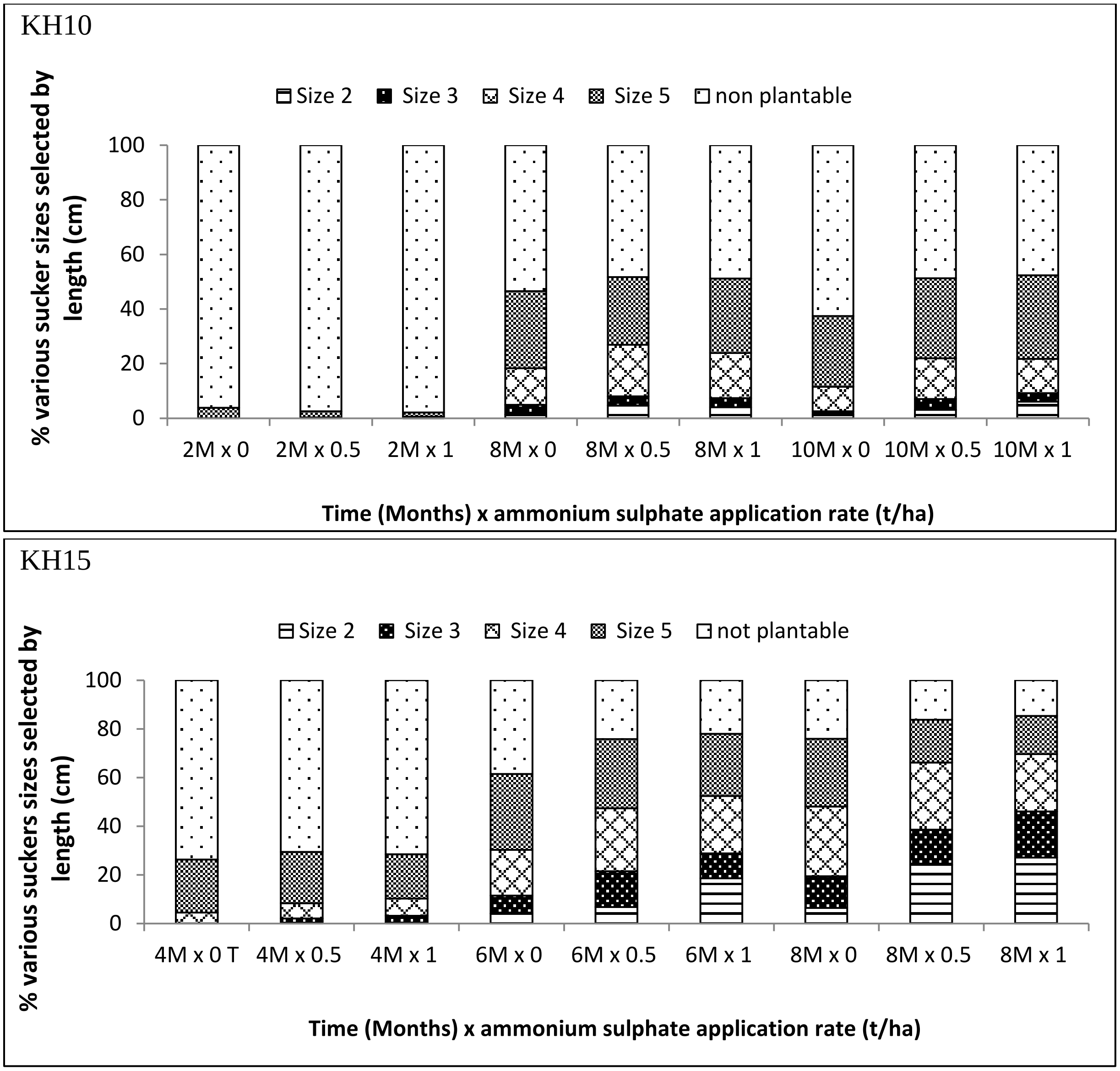


Figure 3.4. Interaction of duration of sucker growth on mother plant and post-harvest $(NH_4)_2SO_4$ application on the percentage of various sucker sizes selected by length (cm), in KH10 and KH15 . M = months, 0 = 0 ton/ha $(NH_4)_2SO_4$, 0.5 = 0.5 ton/ha $(NH_4)_2SO_4$ and 1 = 1 ton/ha $(NH_4)_2SO_4$.

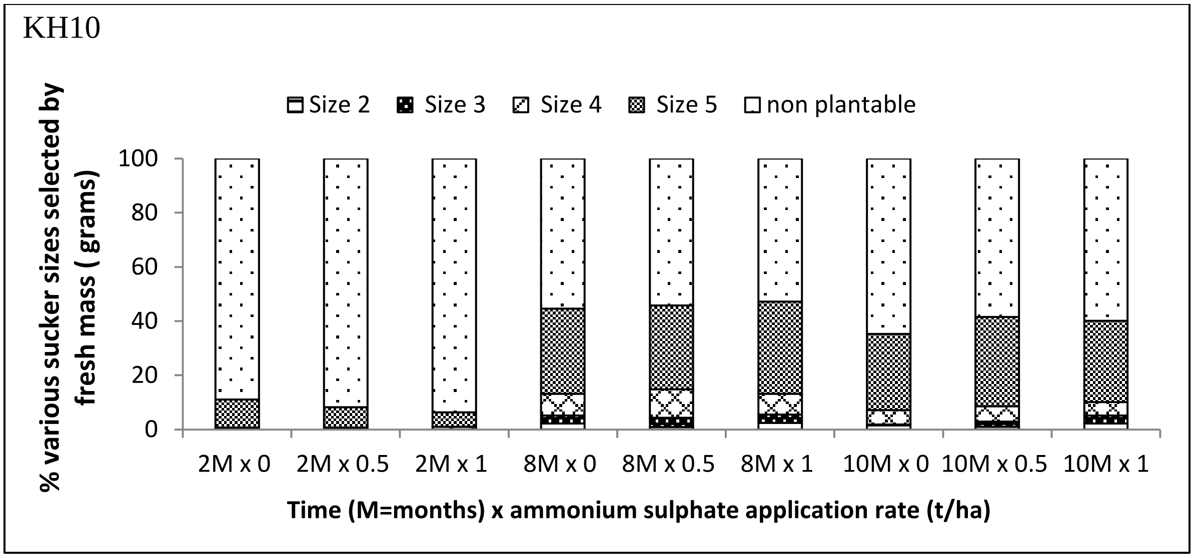
Interaction effect

KH10

There was no significant interaction effect between time and post-harvest $(NH_4)_2SO_4$ application on the number and size of suckers selected by fresh mass (Fig. 3.5).

KH15

The percentage of plantable suckers increased with an increase in the duration of sucker growth on the mother plant in KH15 (Fig. 3.5). The average percentage of larger suckers was higher at 6 and 8 months in plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$, than in plants in the 0 ton/ha $(NH_4)_2SO_4$ treatment (Fig. 3.5). The highest average number of plantable suckers was at 8 months while the lowest average number of plantable suckers was at 4 months (Fig. 3.5). At 6 months, the production of sucker size 2 was influenced by the application of 1 ton/ha post-harvest $(NH_4)_2SO_4$ application. At 8 months, plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application had a significantly higher percentage of sucker size 2 than plants in the 0 ton/ha $(NH_4)_2SO_4$ treatment (Fig. 3.5). The highest percentage of plantable suckers (67%) was at 8 months in plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$. The lowest percentage of plantable suckers (25%) was at 4 months in plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 3.5).



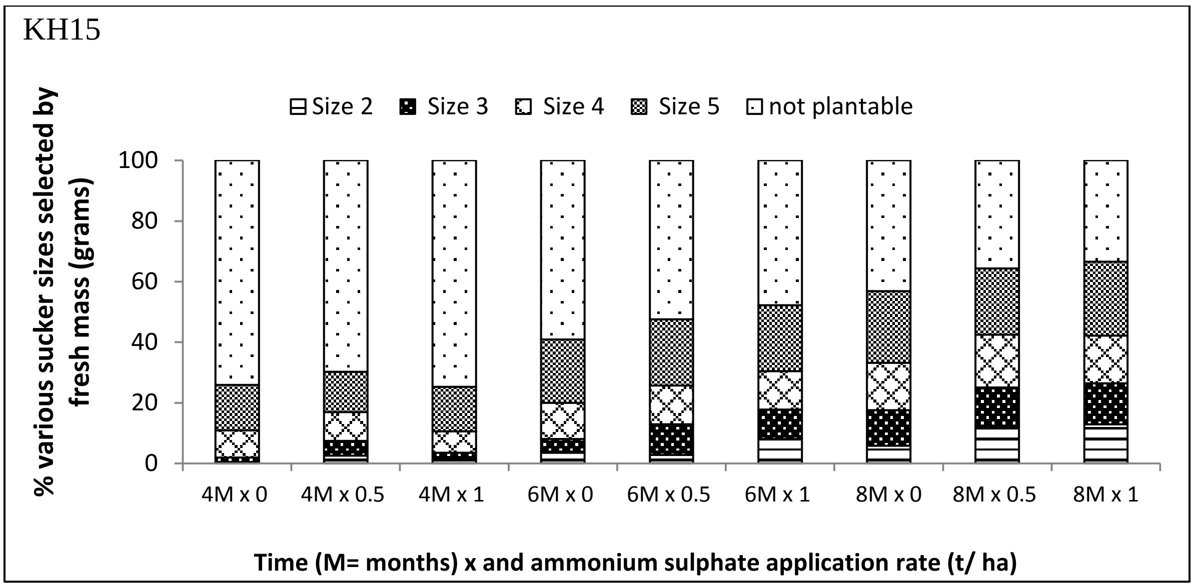


Figure 3.5. Interaction of duration of sucker growth on mother plant and post-harvest $(NH_4)_2SO_4$ application on the percentage of various sucker sizes selected by fresh mass (grams), in KH10 and KH15. M = months, 0 = ton/ha $(NH_4)_2SO_4$, 0.5 = 0.5 ton/ha $(NH_4)_2SO_4$ and 1 = 1 ton/ha $(NH_4)_2SO_4$.

3.3.3 Mother plant growth

The effect of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application had no significant effect on stem length and stem diameter of the mother plant (data not shown) in contrast with time which had a significant effect on stem length and diameter of the mother plant.

The effect of growth duration (time)

In the KH10, the length and diameter (Table 3.5) of the stem of the mother plant increased significantly by 12.4% and 30.7% respectively from 2 months to 8 months after post harvest $(NH_4)_2SO_4$ application. Rather than increasing, the length and diameter of the stem of the mother plant decreased from 8 to 10 months after post harvest $(NH_4)_2SO_4$ application by 2.5% and 0.4% respectively. However, the decreases from 8 to 10 months were not statistically significant (Table 3.5). In block KH15, the stem length and diameter increased significantly from 4 months to 6 months after post harvest $(NH_4)_2SO_4$ application by 21.8% and 15.5% respectively, but decreased by 1.5% and 2.1% respectively, from 6 to 8 months after post harvest $(NH_4)_2SO_4$ application (Table 3.5). The actual data used to calculate the percentages is presented in Appendices (Table 2 A and B).

Table 3.5. Effect of time (months) on mother plant stem length and diameter.

Block KH10		Block KH15	
Time interval after post-harvest $(NH_4)_2SO_4$ application	Increase in mother plant stem length (%)	Time interval after post-harvest $(NH_4)_2SO_4$ application	Increase in mother plant stem length (%)
2 - 8 months	12.4	4 - 6 months	21.8
8 - 10 months	-2.5	6 - 8 months	-1.5
$LSD_{0.05}$	8.8	$LSD_{0.05}$	14.4
	% mother plant stem diameter increase		% mother plant stem diameter increase
2 - 8 months	30.7	4 - 6 months	15.5
8 - 10 months	-0.4	6 - 8 months	-2.1
$LSD_{0.05}$	29	$LSD_{0.05}$	5.7

3.4 DISCUSSION

3.4.1 Sucker growth and development on mother plant

The 2 blocks in this study reacted differently to the application of post-harvest $(NH_4)_2SO_4$ application. In KH10 the benefit gained from the application of post-harvest $(NH_4)_2SO_4$ was less than in KH15 which indicates that plants must be in a healthy state to make maximum use of applied fertilizers. Post-harvest $(NH_4)_2SO_4$ application had a significant influence on sucker growth on the mother plant over time and yielded more plantable suckers of larger sizes. These results support the findings of various authors (Melton and Dufaults, 1991a; Mohammad et al., 2012; Pervez et al., 2004) who reported that nitrogen played a major role on increasing fresh shoot mass and plant height. In other plants, e.g. in rice, Azarpour et al.(2011) reported that nitrogen application at main crop harvest increases tillers length produced in ratoon rice crops compared to when no nitrogen is given.

The results also supported the second hypothesis that the growth of the sucker in fresh mass and length is determined by the length of time they grow on the mother plant. The decline in sucker fresh mass and length in KH10 from 8 to 10 months after post-harvest $(NH_4)_2SO_4$ application could be attributed to the fact that as the suckers grow old on the mother plant they start drying out from the tips of their leaves therefore decreasing the fresh mass and length. It could also be due to the decline in nutrients from the mother plant, as well as, in this case, the effect of the winter stress which results into reduced new leaf formation. There is also a possibility that carbohydrates and nutrients stored in the suckers could be translocated elsewhere in the mother plant, maybe to support growth of new suckers.

3.4.2 Grading of suckers in sizes

Development of the auxiliary buds into suckers starts well before harvest in the Queen cultivar. Vigorous growth though only takes place after fruit harvest (Maerere, 1997). The maximum potential for sucker growth and development depends on the number of auxiliary buds that have started to grow as well as the time taken for growth (Py et al., 1987). The present study shows that harvesting the suckers too early (up to 4 months after harvest) will yield only small suckers (class size 5), while a longer growth cycle will allow the suckers grow larger . Application of post-harvest N fertilizer enhances growth and therefore yielding more suckers of a larger size (class size 2). The same outcomes were found by Dalldorf (1992): high nitrogen resulted in more suckers on the cayenne pineapple. Suckers should also not be grown for too long on the mother plant as a decline in vigour occurs as experienced in KH10.

Block KH10 and KH15 produced varying results in the number and size of plantable material. Growth in KH10 was not as good as in KH15. Probably the fact that the suckers in KH10 were harvested after the winter months could be the reason for the low percentage of suckers produced. In KH10 and KH15, the number of plantable suckers was markedly higher at 8 months than at shorter and longer time durations. These results are supported by the findings of Allison and Pammenter (2002) who found that, the production of tillers in sugar cane reaches its maximum after a certain number of days in the early phase of growth. There was an insignificant change in the number of sugarcane stems produced later during the second half of growth. A significant interaction effect between time and post-harvest $(NH_4)_2SO_4$ was observed on the number and size of plantable suckers produced. The results indicate that the time required to grow suckers on the mother plant after fruit harvest and the decision to apply or not apply post-harvest $(NH_4)_2SO_4$, will be determined by the size required. At 4 and 6 months, class size 5 is abundantly produced with or without the application of fertilizer, but when various sucker sizes are required, especially the larger sucker sizes, it is best to apply nitrogen after fruit harvest and let suckers grow for 8 months before they are harvested. Larger sucker sizes are the most desired by the farmers to achieve higher yields. It is important to have all sucker sizes from large to small, because to achieve the year-round production, suckers of different sizes are planted at different times of the year.

Sucker grading is an important tool for ensuring the quality of the planting material. Sucker quality can be enforced by visual inspection to detect physical damage as well as presence of symptoms or signs of diseases and pests. Good quality planting material should have less than 5% of poor quality suckers (Heman and Calle, 2007). The length of time suckers grow on the mother plant had an effect on the percentage of plantable suckers.

There were more plantable suckers when length was used as a grading criterion compared to fresh mass. In commercial pineapple production, grading the pineapple suckers by length is more practical than using mass. It was noted that suckers sorted by length should also have the same stem thickness. The same applies when sorting by fresh mass, whereby plants within each size should be uniform in length and thickness to achieve uniform growth. This helps to achieve a uniform crop stand. Uniform growing plants result into a cost effective crop management programme especially at harvest.

3.4.3 Mother plant growth

Growth of the mother plant was estimated by measuring the stem length and diameter. Leaf formation ceases after flower induction and plant mass of the mother plant after harvest is influenced by the growth of the suckers on the mother plant. Therefore, measuring the stem could indicate whether growth is taking place after harvest. The results showed that there was an increase in post-harvest growth of mother plant stem in terms of length and diameter close to harvesting, but as the time of growth increased there was a decline in mother plant stem length and diameter. Mother plant stem length and diameter was not influenced by post-harvest $(NH_4)_2SO_4$ application. Based on those findings, we can assume that post-harvest $(NH_4)_2SO_4$ application had more influence on the development of the suckers than on the growth of the mother plant. Post-harvest $(NH_4)_2SO_4$ application can be applied at the rate of 1 ton/ha to improve sucker development on the mother. Nonetheless, the stem plays a vital role in the post-harvest growth of suckers. This is because after fruit harvest, the stem becomes the main storage organ for photosynthetic products (Py et al., 1987) when the suckers are still too small. This causes the stem to increase in length and thickness to accommodate the accumulation of the photosynthetic products with time. Lacoeuilhe et al., (1978) found that a 30% increase in stem dry matter occurred in the 3 months following harvest. However, as sucker growth increases after fruit harvesting, the reserves are used by the suckers. Except for ground suckers, stem suckers have no roots and therefore feed only on the reserves previously accumulated by the mother plant (Py et al., 1987), hence the decrease in growth of stem length and diameter.

The pineapple plantings for this trial were planted in April 2007 and harvested in August 2008 after which, $(NH_4)_2SO_4$ treatment was applied, therefore, the results of the soil fertility status of the trial site taken prior to planting was not expected to have any influence in the findings of the study.

CHAPTER 4

EXPERIMENT 2. THE EFFECT OF POST-HARVEST FERTILIZER APPLICATION, PLANTING SUCKER SIZE AND TIME OF PLANTING ON SUBSEQUENT PLANT GROWTH, MORTALITY, FRUIT YIELD AND YIELD QUALITY OF QUEEN PINEAPPLE

4.1 INTRODUCTION

Pineapple yield is dependent on the quality of the planting material, soil preparation, nutrient management, and crop protection amongst many other things. A good plant establishment is a pre-requisite for a good yield (Py et al., 1987). In Hluhluwe, plant mortality as well as poor growth and development of the Queen pineapple are some of the major problems facing pineapple producers. Outcomes from discussions with pineapple farmers in Hluhluwe indicate that all the farmers suffer the same problem of plant mortality and poor development, although they do not really know the extent of the problem. Whilst the Queen pineapple is planted at a density of 100 000 – 130 000 plants per hectare, the percentage of fruit harvested by most of the farmers is much less than expected at these populations and ranges from 72 to 78% fruit per hectare. Reject fruit (fruit too small, damaged or with disease symptoms) contributes 3 to 5% of the loss (Rabie, 2008). Therefore, approximately 20% of the plants do not produce fruit due to death or poor growth. The causes of poor growth are not clear, but the plants die back or develop very slowly after planting, ending up being too small to produce fruit at the time of flower induction with consequent yield reduction and lower returns to farmers (Rabie, personal communication). Eliminating the causes of poor growth will enhance pineapple yield.

Quality of the planting material is one of the most important factors that affect plant growth. Currently, Queen pineapple plantings are established from suckers taken from harvested plants. Suckers grow on the mother plant for a certain time after harvesting the fruit, before it is ready to be used as planting material. Fertilizer (mainly N) can be applied after harvesting to promote sucker growth. At planting, suckers are selected and sorted according to their size (Bartholomew et al., 2003).

Trials were conducted to examine the effect of post-harvest $(NH_4)_2SO_4$ application, sucker size and sucker growth duration on the mother plant on subsequent plant growth, yield and fruit quality, as well as to determine how long the effect of post-harvest fertilizer application will carry over in the subsequent plantings. Obiefuna et al., (1987) found that Cayenne pineapple plants supplied with nitrogen in the first crop produced larger sucker sizes and a higher yielding ratoon crop than the plants that received no nitrogen. In chapter 3 it was determined that $(NH_4)_2SO_4$ and the duration of sucker growth on the mother plant had an effect on sucker sizes. This chapter examines the effect of duration of sucker growth, sucker size and post-harvest $(NH_4)_2SO_4$ application on subsequent plant growth as well as fruit and sucker yield.

The tested hypotheses were that: 1. healthy plants produce higher yields. 2. The size of the planting material and the time of planting influence plant growth and fruit yield.

4.2 METHODS AND MATERIALS

Three trials were conducted in 2009 at Kleynfaan Estate (S 28° 0' 50"; E 32° 16' 30") in Hluhluwe, KwaZulu Natal, to determine the effect of different rates of post-harvest $(NH_4)_2SO_4$ application, duration of sucker growth and sucker size on subsequent growth and yield in pineapple plantings.

Planting material (suckers) was collected at 6 months (March), 8 months (May) and 10 months (August) after post-harvest application of different $(NH_4)_2SO_4$ rates (see chapter 3) from two planting blocks, namely KH15 (March, May) and KH10 (August) to represent 3 different durations of sucker growth. Suckers of each of the fertilizer treatments (0, 0,5 and 1 ton/ha $(NH_4)_2SO_4$) were sorted into four different sizes (sizes, 2, 3, 4 and 5) and a sample of 30 plants of each sucker size was measured to determine the average sucker length and stem diameter. This was done to confirm that plant size did not differ between the three plantings (see chapter 3 for results).

The 12 treatments (three $(NH_4)_2SO_4$ rates x four plant sizes) were replicated 3 times in a randomized block design. Each replicate was planted on 4 ridges with 6 plant rows per ridge and 22 cm between plants. The size of each replicated block was therefore 7.2 m (ridge width = 1.8 m) x 5 m. The total size of each trial area was 0.13 ha (7.2 m x 5 m x 12 treatments x 3 replicates). The first and fourth ridges were border ridges. The second ridge was used for destructive data collection where plants were sampled to measure plant growth, evaluate insect infestation and sample leaves for analysis. The third ridge was used for plant mortality evaluation, counting flowering percentages as well as for yield assessment. Four meters of ridge, containing ±110 plants, was demarcated for these assessments. Table 4.2 represents the time frame and activities carried out in the plantings.

A randomized complete block design (Table 4.1) was used in all three plantings. The same trial layout was used in the March, May and August planting.

Eight months after fruit harvest, in the March and May plantings, 10 plants per replicate of the post-harvest $(NH_4)_2SO_4$ and sucker size treatments were randomly selected. A zigzag method of sampling was used to select 10 plants in a ±4 meter ridge (representing a total of 100 plants). The sample represented healthy plants and plants affected by the mortality symptoms, and were evaluated for sucker yield.

Only the data of healthy plants, plants planted too deep and wilted plants are presented. Plants that toppled over and those affected by the funnel rot, were marked by a poor quality paint which washed off on most of the plants, as a result a representative sample could not be obtained. Slow growing plants and the plants that died back failed to produce plantable suckers.

Table 4.1. A split plot design of 3 different planting dates (sucker growth duration), 3 fertilizer rates 0 ton/ha (control), 0.5 ton/ha and 1 ton/ha $(NH_4)_2SO_4$ and four sucker (sizes 2, 3, 4 and 5).

Planting dates/sucker growth duration	**Treatment**		
	Fertilizer	**Sucker size**	**Treatment number**
March planting 6 months after post-harvest fertilizer application	Control (no fertilizer applied)	2	1
		3	2
		4	3
		5	4
	0.5 ton ammonium sulphate/ha	2	5
		3	6
		4	7
		5	8
	1 ton ammonium sulphate/ha	2	9
		3	10
		4	11
		5	12
May planting 8 months after post-harvest fertilizer application	Control (no fertilizer applied)	2	1
		3	2
		4	3
		5	4
	0.5 ton ammonium sulphate/ha	2	5
		3	6
		4	7
		5	8
	1 ton ammonium sulphate/ha	2	9
		3	10
		4	11
		5	12

Planting dates/sucker growth duration	**Treatment**		
	Fertilizer	**Sucker size**	**Treatment number**
August planting 10 months after post-harvest fertilizer application	Control (no fertilizer applied)	2	1
		3	2
		4	3
		5	4
	0.5 ton ammonium sulphate/ha	2	5
		3	6
		4	7
		5	8
	1 ton ammonium sulphate/ ha	2	9
		3	10
		4	11
		5	12

Table 4.2 Time frames of the study activities.

Date & Activities	Mar 09	May 09	Aug 09	Sep 09	Nov 09	Dec 09	Feb 10	Mar 10	Apr 10	Jun 10	Jul 10	Nov 10	Feb 11	Jul 11
Month no.	1	3		7		10	12			17			24	
March planting	*P	*ME (1)		*ME (2) + *PGE +* I		*FI + *PGE	*F%			*H			*SGE	
Month no		1	3			7		10		13		18		26
May planting		P	ME (1)			ME (2) + PGE + I		FI + PGE		F%		H		SGE
Month no			1		3			7	8		11	15		
August planting			P		ME (1)			ME (2) + PGE + I	FI + PGE		F%	H		

*P = Planting, ME (1) = Mortality Evaluation 2 months after planting, ME (2) = Mortality Evaluation 6 months after planting, PGE = Plant Growth Evaluation, I = Insect infestation evaluation, FI = Flower Induction, F% = Flowering percentage, H = Harvest, SGE = Sucker Growth Evaluation

Table 4.3. Shows the accumulative rainfall Figures for the 3 to 6 months after planting for each of the plantings. The table also gives the number of days before planting that the rain had fallen, as well as the amount of rainfall .

Table 4.3. Accumulative rain for the 6 months after planting for the March, May and August plantings.

	March planting 19-03-09	May planting 21-05-09	August planting 04-08-09
No. of days since lrbp	2	12	1
Mm of lrbp	8.4	12	23
No of days bppr	18	19	16
Mm of first rain pp	2	4.2	7
3 months	47.8	47	215.2
4 months	51	50.9	353.5
5 months	78.2	229.6	406.1
6 months	89.1	352.2	455.9

lrbp = last rain before planting, bppr = before post planting rain, pp = post plant

4.3. ASSESSMENTS

4.3.1 Plant growth and development

Assessment of plant growth and development was done during the vegetative growth stage, which, depending on growing conditions, varied between 7 and 9 months before artificial flower induction. As a result, the March and May planting were evaluated at 6 months and 9 months after planting. Due to poor growing conditions, artificial flower induction (using ethephon) in the August planting was done 2 months earlier than the other plantings. Therefore, the plant growth evaluations were done at 6 and 7 months. Ten plants in each of the post-harvest $(NH4)_2SO_4$ and sucker size treatments were randomly selected on each of the two occasions. A zigzag method of sampling was used in a ±4 meter ridge (representing a total of 100 plants). Fresh plant mass and stem diameter of the plants were measured.

4.3.2 Plant mortality

Plant mortality and growth were evaluated at 2 and 6 months after the planting of the suckers. At 2 months, ±4 meter of ridge 3 (representing a total of 100 plants) in each replicate of each post-harvest $(NH_4)_2SO_4$ and sucker size treatment were selected for evaluation of plant mortality symptoms. The plants were colour coded with aerosol spray paint to indicate the type of symptoms that were found.

There were 6 plant mortality symptoms identified namely:

(i) Wilted: plants turning red, leaves twisting under and drying of the tips (Fig. 4.1).

Figure 4.1. A wilted plant, marked by blue aerosol paint. Picture taken at 2 months after planting in a plot planted with sucker size 2.

(ii) Toppled over: plants that have fallen over or are slanted at an angle therefore not standing upright (or straight up). This was caused by the wind and some were not inserted properly in the soil at planting (Fig. 4.2).

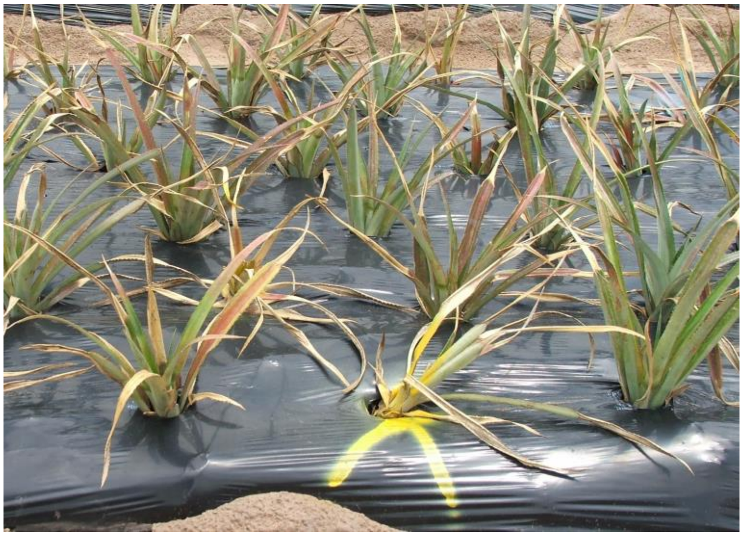


Figure 4.2. A toppled over plant, marked by yellow aerosol paint. Picture taken at 2 months after planting in a plot planted with sucker size 5.

(iii) Too deep: plants planted too deep into the soil therefore soil falls into the funnel and retards growth (Fig. 4.3).

Figure 4.3. A plant that was planted too deep, marked by red aerosol paint. Picture taken at 2 months after planting in a plot planted with sucker size 3.

(iv) Slow growth: plants which develop slowly or are smaller in size compared to the other plants in the treatment (Fig. 4.4).

Figure 4.4. A slow growing plant, marked by white aerosol paint. Picture taken at 6 months after planting in a plot planted with sucker size 2.

(v) Funnel rot: plants with leaves burned by ammonium sulphate fertilizer when it falls into the funnel of the plant at application. The leaves dry out and fall off therefore affecting the development of the plant (Fig. 4.5).

Figure 4.5. A plant affected by the funnel rot, marked by pink aerosol paint. Picture taken at 4 months after planting in a plot planted with sucker size 2.

(vi) Dying back: plants with no sign of active growth and with most of the leaves drying out and falling off (Fig. 4.6).

Figure 4.6. A plant that was dying back, marked by purple aerosol paint. Picture taken at 2 months after planting in a plot planted with sucker size 2.

The plants that were tagged with mortality symptoms at 2 months after planting were subsequently evaluated for growth progress at 6 months after planting. It was observed that the plants were developing in three different ways namely: growing slowly, dying or improving in health. The number of plants that developed in a certain way at the 6 month evaluation, is presented as a percentage of the number of plants that showed a specific symptom at 2 months.

4.3.3 Insects evaluation

At 6 months after planting and at flower induction, 10 plants per replicate of the post-harvest $(NH_4)_2SO_4$ and sucker size treatments were randomly selected from the outer ridge and inspected for infestation with mealybug (*Dysmicoccus brevipes)* and red mite (*Dolichotetranychus floridanus)*. The mealybug and red mite infestation were counted on the basal part of the 10 outer leaves of each plant. The mealybug and red mite infestation was given as the total number of plants infested in each post-harvest $(NH_4)_2SO_4$ and sucker size treatments.

4.3.4 Leaf analysis

The nutritional status of the plants was evaluated at red bud stage. Ten D-leaves per replicate of the post-harvest $(NH_4)_2SO_4$ and sucker size treatments were sampled at random and sent to the laboratory for tissue N, P and K analysis. The pineapple plants leaves were dried and ground in a Wiley grinder (mesh 60 cm-2). Then the powder was sulfuric acid-digested combined with hydrogen peroxide to determine the total contents of N, P, K. For N, the Nessler Method was used and for P molecular absorption spectrophotometry (colorimetry, at 725 nm wavelength), after reaction with ascorbic acid and ammonium molybdate. The K content was determined by flame photometry. All analyses were performed according to the commonly used methods for pineapple (Baldotto et al., 2009).

4.3.5 Flower percentage

One hundred plants per replicate in the demarcated area in each $(NH_4)_2SO_4$ and sucker size treatment were inspected for flowering at red bud stage to establish the percentage of (1) plants that did not flower (a) among plants with mortality symptoms and (b among normal looking plants in response to flower induction treatment, as well as (2) plants that flowered naturally in the absence of flower induction treatment.

4.3.6 Fruit yield

A total of 100 fruit were harvested and weighed per replicate. The 100 fruit were picked from the demarcated 4 m of the third ridge, starting at one end, picking all fruit until 100 had been picked. The potential yield was calculated using the formula Y= X x D x FW/1000000 (Y = t/ha, X = percentage of plants with fruit, D = planting density/ha and FW = average fruit mass (g/fruit)). The actual yield was calculated by subtracting the estimated loss due to mortality symptoms from the potential yield. The estimated loss was calculated by counting the total number of plants with mortality symptoms that had failed to flower. The estimated fruit mass was obtained by calculating the average fruit mass in each treatment, which was then converted to tons/ha.

4.3.7 External and internal fruit evaluation at harvest

Ten fruit per replicate were randomly selected at harvest. The fruit crown was removed from the fruit and weighed on a scale. The crown length as well as the fruit length were also measured with a tape and the total number of fruitlets on the fruit spiral counted. The fruit was then inspected for inter-fruitlet cracking and the occurrence of winter speckle. The number of solid winter speckle rings as well as the percentage fruit covered with winter speckle were noted. The total soluble solids (TSS) or percentage sugar in the fruit was measured in degrees °Brix by means of a hand-held refractometer.

4.3.8 Post-harvest fruit evaluation

Ten fruit per replicate of the $(NH_4)_2SO_4$ and sucker size treatments were stored at room temperature. Of these, 5 fruitS were inspected after 7 days of storage and the other 5 after 14 days of storage. The occurrence of black spot in the seed cavity and nectary duct infection as well as internal browning were noted. The fruit was cut into slices of 1 cm thickness to count and record the number of nectary duct and black spot infections visible per fruit slice. Internal browning was assessed by rating the discolouration of the tissue in and around the fruit core. The rating index: 1 = first sign of browning around the fruit core, 2 = ¼ of the fruit core covered in browning, 3 = ½ of the fruit core covered in browning and 4 = the complete browning around the fruit core.

4.3.9 Post-harvest sucker yield evaluation

Eight months after fruit harvest, suckers from 10 randomly selected plants per replicate of the smallest unit, each representing healthy plants and plants affected by the mortality symptoms, were graded by mass (≥50g) and length (≥30cm) to determine the effect of plant size, plant health and post-harvest $(NH_4)_2SO_4$ application on sucker yield.

Figure 4.7. Plants affected by the mortality symptoms and a healthy plant, picture taken at 8 months after fruit harvest. Plant no 1 = funnel rot, 2 = wilted, 3 = dying back, 4 = planted too deep. 5 = toppled over, 6 = slow growing and 7 = healthy

4.3.10 Statistical analysis

Data were analysed using Genstat twelfth edition (Genstat, 2009). Significant difference among the means was determined by LSD at the $P \leq 0.05$ probability level. Correlations were done using Sigma Plot Statistics 12.0 (Systat Software, 2010).

4.4 Results

4.4.1 Plant growth and development after planting

4.4.1.1 Average percentage gain in plant fresh mass from planting to flower induction, i.e. 9 months after planting in the March and May planting, and 7 months after planting in the August planting

Post-harvest $(NH_4)_2SO_4$ application had a significant effect ($p < 0.05$) on subsequent plant growth. Plant fresh mass increased only at post-harvest $(NH_4)_2SO_4$ application rate greater than 0.5 ton/ha in the March planting (Fig. 4.8A).In the May and August plantings, there was an increase in plant fresh mass with an increase in post-harvest $(NH_4)_2SO_4$ application (Fig. 4.8 B and C).

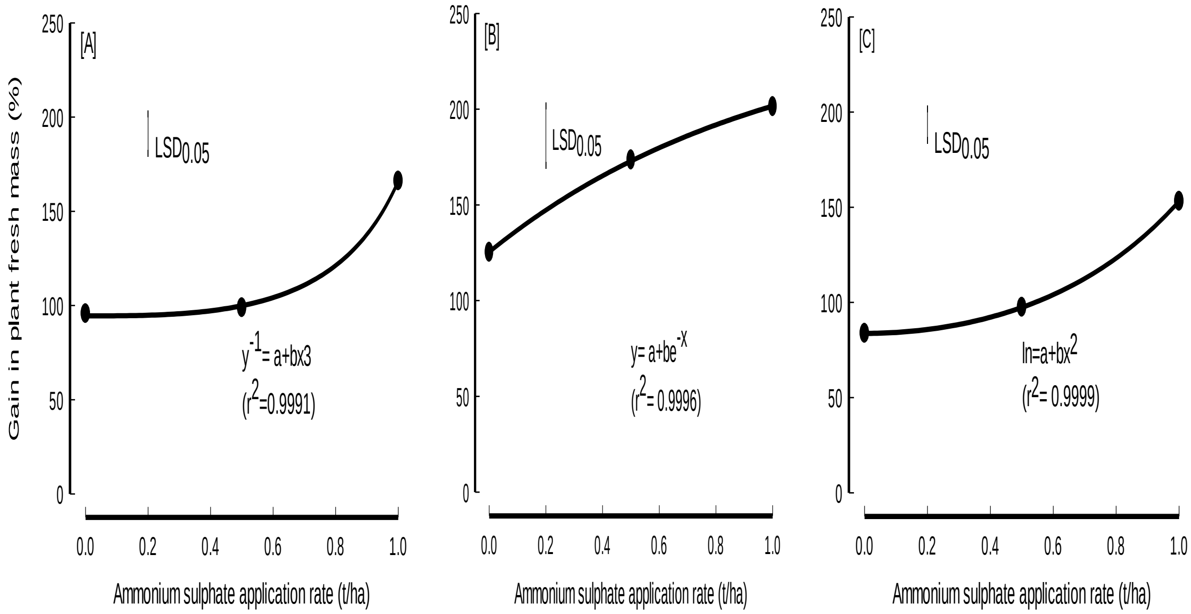


Figure 4.8. Effect of post-harvest $(NH_4)_2SO_4$ application on the average percentage gain in plant fresh mass from planting to 9 months after planting in the March planting [A] and May planting [B], as well as from planting to 7 months in the August planting [C]. (Data points are means of 3 replications).

Percentage gain in plant fresh mass was positively correlated with the sucker sizes at planting, but the relationship depended on the time the suckers were planted after post-harvest $(NH_4)_2SO_4$ application. The highest average percentage gain in plant fresh mass was in the May planting while the lowest average gain in plant fresh mass was found in the March planting. Sucker size had no significant effect ($p < 0.05$) on the percentage gain in fresh mass in the March planting (Fig. 4.9 A). In the May planting, the gain in fresh mass was larger in the smaller sucker sizes (Fig. 4.9 B). In the August planting, there were no differences in fresh masss of plants established from sucker sizes 3 and 4. Plants established from sucker size 5 had a significantly higher percentage gain in fresh mass than plants established from sucker size 2, 3 and 4 (Fig.. 4.9 C).

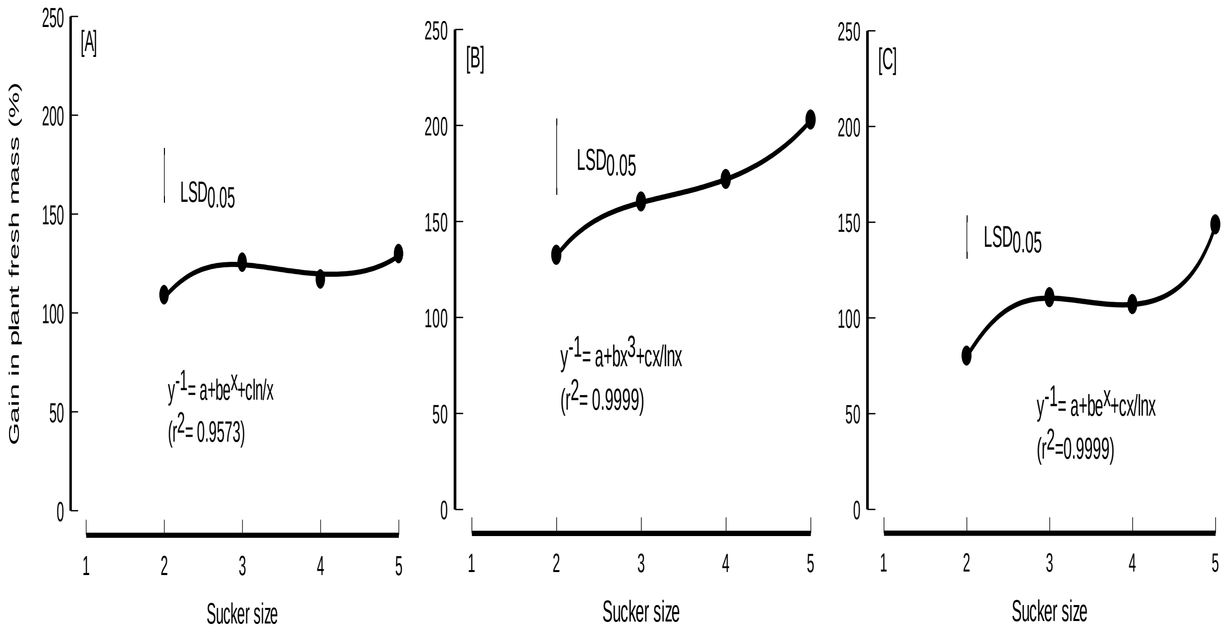


Figure 4.9. Effect of sucker size on the average percentage sucker gain in plant fresh mass from planting to 9 months after planting in the March planting [A] and May planting [B], as well as from planting to 7 months in the August planting [C]. (Data points are means of 3 replications).

Time of growth (6 or 9 months after planting) had a significant effect on the percentage increase in plant fresh mass (Table 4.4). From planting to 6 months after planting, the highest percentage gain in plant fresh mass was in the August planting established from suckers planted 10 months after post-harvest $(NH_4)_2SO_4$ application (Table 4.4). The lowest percentage gain in plant fresh mass from planting to 6 months after planting was found in plants established from suckers planted 6 months after post-harvest $(NH_4)_2SO_4$ application (March planting) (Table 4.4). The highest percentage gain in plant fresh mass from planting to 9 months after planting, was in plants established from suckers planted 8 months after post-harvest $(NH_4)_2SO_4$ application (May planting).The May planting also had the highest average percentage gain in fresh mass during the entire vegetative stage of growth, while the August planting had the lowest percentage gain in fresh mass (Table 4.4).

Table 4.4. Effect of time (months after planting) on the average percentage gain in plant fresh mass.

	Gain in fresh mass (%)			
Time of growth after planting	March planting	May planting	Time of growth after planting	August planting
6 months	98.2	105	6 months	144.1
9 months	141.9	227.4	7 months	78.7
$LSD_{0.05}$	17	25.5	$LSD_{0.05}$	13.4

In the March planting, the percentage gain in plant fresh mass was higher between 6 and 9 months after planting than between planting and 6 months thereafter (Table 4.5). In the March and August plantings, plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application had a higher average percentage gain in plant fresh mass than the plants treated with 0.5 ton/ha or 0 ton/ha post-harvest $(NH_4)_2SO_4$ (Table 4.5). In the August planting, sucker size 5 in all the fertilizer treatments had a higher gain in plant fresh mass than all the sucker sizes in the first 6 months of vegetative growth (Table 4.5).

Table 4.5. Interaction effect between post-harvest $(NH_4)_2SO_4$ application rate and sucker size in the March and August plantings on the percentage gain in plant fresh mass during the vegetative stage of growth.

		Gain in fresh mass (%)			
		March Planting		August planting	
Ammonium sulphate	Sucker size	6 months after planting	9 months after planting	6 months after planting	7 months after planting
0 ton/ha	2	34.5	154.5	8.6	131.1
	3	119.4	101.5	51.3	114.7
	4	91.1	68.8	27.4	137.1
	5	96.8	98.5	126.6	72.6
0.5 ton/ha	2	59.4	125.7	54.1	70.6
	3	107.4	81.3	136.9	54.4
	4	91.8	111.8	102.9	53.7
	5	116.9	94.9	201.3	105
1 ton/ha	2	94.1	184.3	165.8	49.5
	3	125.2	216.7	253.2	51.9
	4	84	253	279.7	39.8
	5	158.1	212.1	321.4	63.3
$LSD_{0.05}$		59		46.7	

There was a positive correlation between post-harvest $(NH_4)_2SO_4$ application rate and the percentage gain in plant fresh mass in the May planting in the last 3 months of vegetative growth (Fig. 4.10 B). The highest percentage gain in plant fresh mass (324%) was at 9 months after planting in plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application, while the lowest percentage gain in plant fresh mass (78.7%) was at 6 months after planting in plants treated post-harvest with 1 ton/ha $(NH_4)_2SO_4$ (Fig. 4.10A). Post-harvest $(NH_4)_2SO_4$ application and the duration of sucker growth after planting had no significant effect on the percentage gain in plant fresh mass, in the March and August plantings (data not shown).

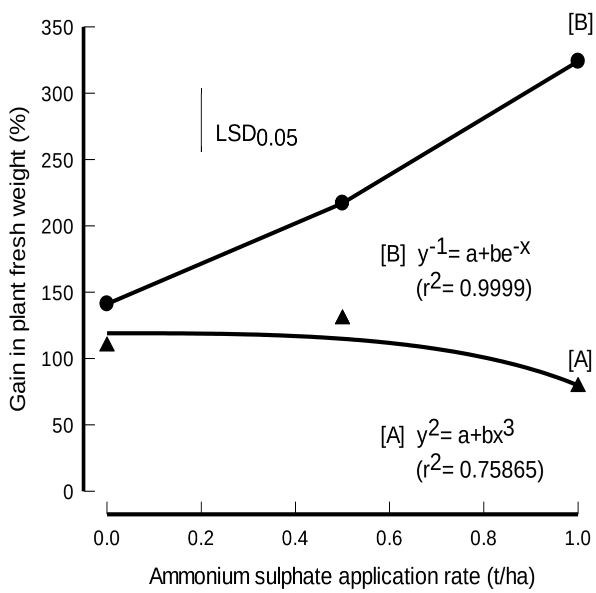


Figure 4.10. Effect of post-harvest $(NH_4)_2SO_4$ application rate and duration of plant growth on the average percentage gain in plant fresh mass at 6 months after planting [A] and 9 months after planting [B], in the May planting. (Data points are means of 3 replications).

4.4.1.2 Average percentage gain in sucker stem diameter at red bud stage in the March, May and August plantings

Post-harvest $(NH_4)_2SO_4$ application had a significant effect ($p < 0.05$) on the growth of stem diameter during the vegetative stage. In all plantings, the stem diameter in subsequent plant growth increased with an increase in post-harvest $(NH_4)_2SO_4$ application (Fig. 4.11 A, B and C). Differences due to post-harvest $(NH_4)_2SO_4$ application were highly significant and positively correlated with the rate applied (Fig. 4.11 A, B and C).

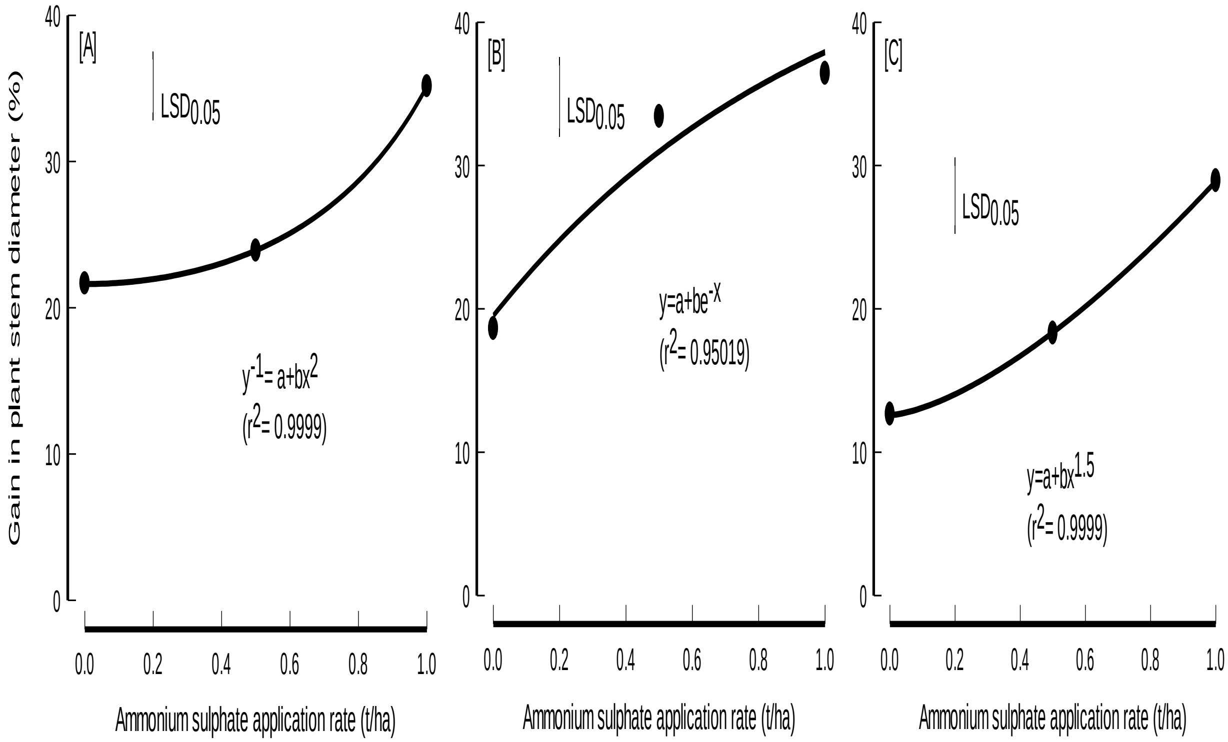


Figure 4.11. The effect of post-harvest $(NH_4)_2SO_4$ application rate on the average percentage gain in plant stem diameter at 9 months after planting in the March planting [A] and the May planting [B] as well as from planting to 7 months after planting in the August planting [C]. (Data points are means of 3 replications).

Stem diameter growth was strongly correlated with the original sucker sizes at planting but the correlation varied with the time the suckers were planted after post-harvest $(NH_4)_2SO_4$ application (Fig. 4.12 A to C). The highest average percentage gain in stem diameter was in the May planting (Fig. 4.11 B), while the lowest percentage gain was found in the August planting (Fig. 4.12 C). In the March planting, the percentage gain in stem diameter was higher in plants established from sucker size 3 than from the rest of the sucker sizes (Fig. 4.12 A). In the May and August plantings, the highest percentage gain in stem diameter was in the plants established from sucker size 5 and the lowest percentage gain was in the plants established from sucker size 2 (Fig. 4.12 B and C).

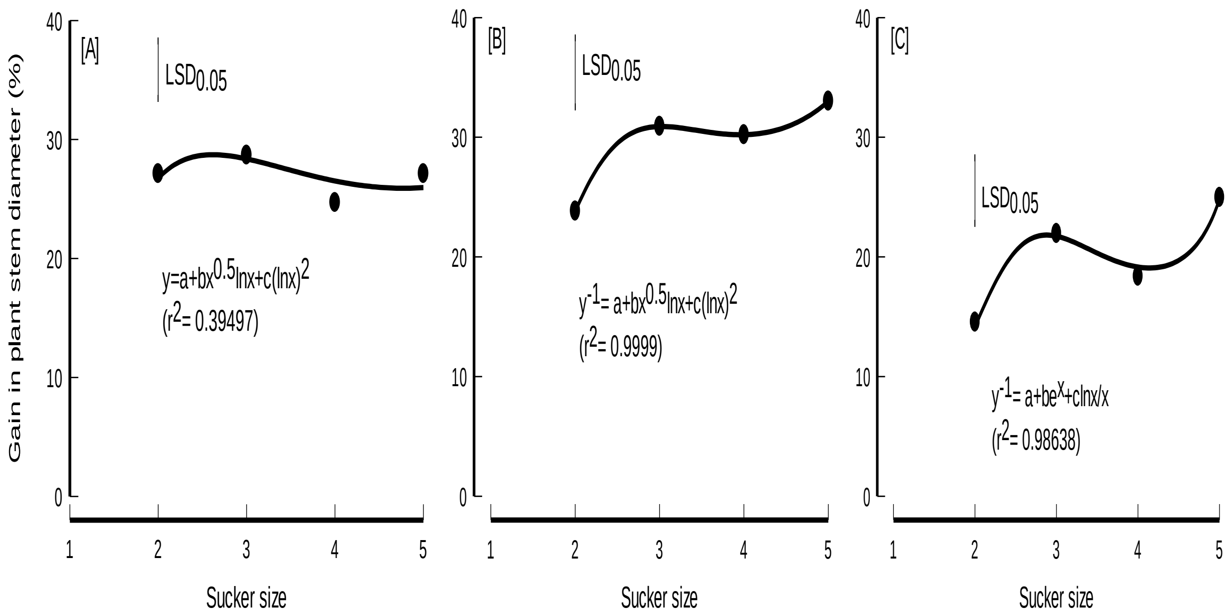


Figure 4.12. Effect of sucker size on the average percentage gain in plant stem diameter from planting to 9 months after planting in the March planting [A] and the May planting [B], as well as from planting to 7 months in the August planting [C]. (Data points are means of 3 replications).

Time of growth (6 or 9 months after planting) had a significant effect ($P < 0.05$) on the percentage gain in plant stem diameter in the March and May plantings (Table 4.6). The highest average percentage gain in stem diameter during the plant's vegetative stage was in the May planting, while the lowest percentage gain in stem diameter was in the August planting between 6 and 7 months after planting (Table 4.6). In the March planting, the highest percentage gain in stem diameter was in the first 6 months after planting while in the May planting the highest percentage gain in stem diameter was in the last 3 months of vegetative growth (Table 4.6).

Table 4.6. Effect of the time (months) of plant growth after planting on the average percentage gain in plant stem diameter.

Time of growth after planting	Gain in plant stem diameter (%) March planting	May planting	Time of growth after planting	August planting
6 months	32.8	18.4	6 months	22.8
9 months	20.9	40.6	7 months	17
LSD $_{0.05}$	3.4	4	LSD $_{0.05}$	NS

Significant interaction effects were found between post-harvest $(NH_4)_2SO_4$ application and sucker size on the percentage gain in plant stem diameter in the March and August plantings (Table 4.7). In the March planting, the average percentage gain in stem diameter throughout the vegetative growth period was higher in the plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ than in the plants treated with 0.5 ton/ha or 0 ton/ha post-harvest $(NH_4)_2SO_4$ (Table 4.7). In the August planting, the highest percentage gain in stem diameter was in plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$, in the first 6 months after planting. There was loss in stem diameter in plants not treated with post-harvest $(NH_4)_2SO_4$ application, established from sucker size 2 and 4 at 6 months after planting (Table 4.7). It was noted that in the August planting, the plants not treated with post-harvest $(NH_4)_2SO_4$ application, had a higher percentage gain in stem diameter from 6 to 7 months after planting, than they had gained from planting to 6 months (Table 4.7).

Table 4.7. Interaction effect between post-harvest $(NH_4)_2SO_4$ application rate and sucker size in the March and August plantings on the percentage gain in plant stem diameter.

		% stem diameter growth			
		March planting		August planting	
Ammonium sulphate	Sucker size	6 months after planting	9 months after planting	6 months after planting	7 months after planting
0 ton/ha	2	21.07	14.26	-3.8	17.36
	3	42.17	6.62	2.64	27.33
	4	28.8	12.16	-5.43	30.53
	5	32.41	15.72	15.46	16.92
0.5 ton/ha	2	40.92	13.08	13.76	15.3
	3	33.01	16.79	25.68	12.98
	4	23.59	20.56	16.95	10.08
	5	18.99	24.21	25.82	25.65
1 ton/ha	2	39.62	33.7	35.66	8.9
	3	48.48	24.97	47.49	15.49
	4	24.56	38.44	49.11	8.9
	5	40.61	30.73	50.72	15.06
$LSD_{0.05}$		59		11.8	

A significant interaction effect was found between post-harvest $(NH_4)_2SO_4$ application rate and duration of plant growth on gain in stem diameter in the May planting (Fig. 4.13). There was a positive correlation between the percentage gain in stem diameter and post-harvest $(NH_4)_2SO_4$ application rate at 9 months after planting. The highest percentage gain in plant stem diameter (53.7%) was from 6 months to 9 months after planting in plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 4.13B), while the lowest percentage gain in plant fresh mass (15.5%) was from planting to 6 months after planting in plants not treated with post-harvest $(NH_4)_2SO_4$ application (Fig. 4.13A). From 6 to 9 months after planting, stem diameter increased significantly ($p < 0.05$) with an increase in post-harvest $(NH_4)_2SO_4$ application rate (Fig. 4.13B). Post-harvest $(NH_4)_2SO_4$ application and duration of plant growth had no significant effect on growth in stem diameter in the March and August plantings (data not shown).

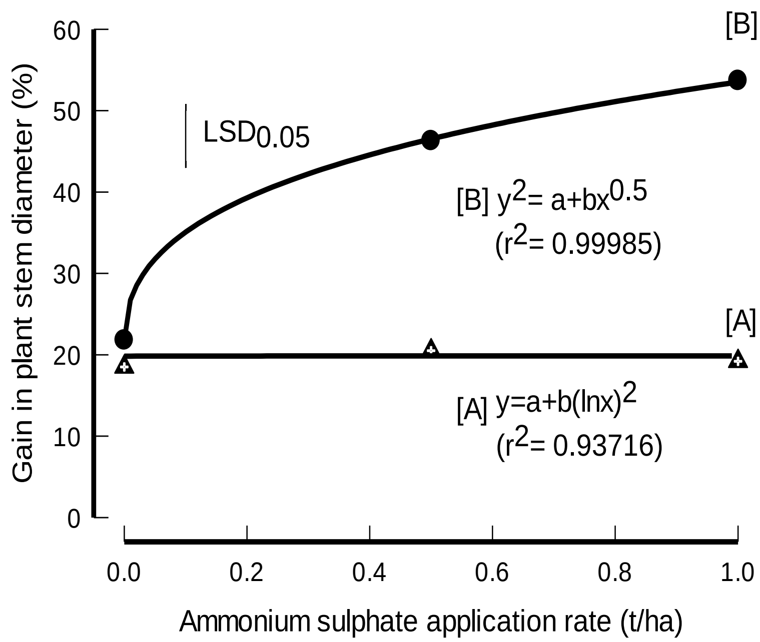


Figure 4.13. Effect of post-harvest $(NH_4)_2SO_4$ application rate and duration of plant growth on the average percentage gain in plant stem diameter from planting to 6 months after planting [A] and from 6 months after planting to 9 months after planting [B], in the May planting. (Data points are means of 3 replications).

4.4.2 Plant mortality

4.4.2.1 Plant mortality at 2 months after planting

The total percentage of plants affected by mortality symptoms was the highest in the August planting and the lowest in the March planting (Table 4.8). Overall the wilted plants and plants that were planted too deep formed a greater proportion of the plants affected by mortality symptoms (Table 4.8). These together constituted 13% in the March planting, 13.3% in the May planting and 23.8% in the August planting. Toppled over plants were low in the March planting, and higher in the May and August plantings (Table 4.8). Funnel rot was only a problem in the March planting. Slow growth was higher in the August planting, than in the March and May plantings. Dying back was only a problem in the May planting.

Table 4.8. Plant mortality symptoms at 2 months after planting.

	Percentage of affected plants		
Plant mortality symptom	March planting	May planting	August planting
Wilted	8.92	5.06	12.67
Too deep	4.58	8.25	11.14
Funnel rot	2.69	0.17	0.03
Toppled over	1.25	6.33	5.28
Slow growth	1.97	1.61	3.08
Dying back	0.25	4.58	0.92
Total% plants showing Mortality symptoms	19.66	26	33.12
$LSD_{0.05}$	1.16	1.57	1.79

Post-harvest $(NH_4)_2SO_4$ application had a significant effect on the percentage of wilted plants and plants planted too deep in the March planting (Table 4.9). The plants in the 0 ton/ha post-harvest $(NH_4)_2SO_4$ application had a significantly higher percentage of wilted plants than the plants treated with 0.5 ton/ha or 1 ton/ha post-harvest $(NH_4)_2SO_4$ application. Plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application, had a significantly higher percentage of plants planted too deep than the plants in the 0 ton/ha or 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ application (Table 4.9). Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the percentage of wilted plants and plants planted too deep in the May and August planting (data not shown).

Table 4.9. Effect of post-harvest $(NH_4)_2SO_4$ application on mortality symptoms in the March planting.

	Percentage of plants affected by the mortality symptoms					
Fertilizer	Wilted	Too deep	Funnel rot	Toppled over	Slow growth	Dying back
0 ton/ha	11.83	4.08	2.67	1.5	1.83	0.75
0.5 ton/ha	7.83	3.5	2.75	0.83	2.42	0
1 ton/ha	7.08	6.17	2.67	1.42	1.67	0
$LSD_{0.05}$	2.01					

Sucker size had a significant effect on the percentage of plants affected by the mortality symptoms in the March, May and August plantings (Table 4.10). In all the plantings, smaller sucker sizes had a significantly less percentage of wilted plants than the larger suckers.. The percentage of plants planted too deep was low in the larger sucker sizes and increased with a decrease in sucker size in all the plantings (Table 4.10). In the

March planting, sucker size 2 had a significantly higher percentage of plants affected by funnel rot than sucker size 4 and 5 (Table 4.10). In the May and August planting an insignificant percentage of plants were affected by funnel rot. In the May planting, the toppling over percentage was higher in sucker size 2 and lower in sucker size 5. Although toppling over was high in the August planting, sucker size had no significant effect (Table 4.10). In all the plantings, sucker size had no significant effect on slow growth, but data shows that larger sucker sizes (size 2) were slightly more affected than the smaller sucker sizes (size 5). In the May planting, dying back was significantly higher in sucker size 5 than in sucker size 2. Sucker size had no significant effect on dying back in the March and August plantings (Table 4.10).

Table 4.10. Effect of sucker size on the percentage of plants affected by the mortality symptoms in the March, May and August plantings.

		Percentage of plants affected by mortality symptoms					
Planting time	Sucker size	Wilted	Too deep	Funnel rot	Toppled over	Slow growth	Dying back
March planting	2	9.33	4	4.56	0.89	2.33	0.78
	3	11.44	4.44	2.56	1.44	2.11	0
	4	8.67	3.67	2.11	1.22	1.89	0.11
	5	6.22	6.22	1.56	1.44	1.56	0.11
$LSD_{0.05}$	2.32						
May planting	2	6.33	5.33	0.33	9	1.78	2.56
	3	6	8.22	0	5.44	1.44	5
	4	4.89	7	0.22	7.78	1.56	3.89
	5	3	12.44	0.11	3.11	1.67	6.89
$LSD_{0.05}$	3.14						
August planting	2	13.22	6.33	0.11	6.89	4.56	1.44
	3	15.11	12.44	0	5.44	3.22	0.67
	4	13.11	14.33	0	3.56	2.44	1
	5	9.22	11.44	0	5.22	2.11	0.56
$LSD_{0.05}$	3.57						

4.4.2.2 Six-month growth progress of plants that showed mortality symptoms 2 months after planting

Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the dead, slow growing or healthy growing plants that were wilted, toppled over, slow growing and dying back in all the 3 plantings (data not shown). Also, sucker size had no significant effect on the dead, slow growing and healthy plants on the plants affected by funnel rot, toppled over, slow growing and dying back in all the plantings (data not shown).

Wilted plants

On average the percentage of wilted plants that improved in health 6 months after planting was highest in the August planting and lowest in the May planting (Table 4.11). The May planting had the highest percentage of slow growing plants followed by the March planting, while the lowest percentage was found in the August planting. The March planting had a markedly high percentage of dead plants, and that percentage decreased in the subsequent plantings being the lowest in the August planting (Table 4.11).

Table 4.11. Proportion of dead, slow growing and healthy growing plants that had been tagged at 2 months after planting as wilted in the March, May and August plantings.

	Percentage of plants		
	March planting	May planting	August planting
Dead plants	8.1	3.7	0.3
Slow growing plants	40.2	50.7	21.4
Healthy plants	51.7	45.6	78.3
$LSD_{0.05}$	10.42	12.75	6.47

Sucker size had a significant ($p < 0.05$) effect on the growth progress of the wilted plants in terms of either dead, slow growing or healthy plants in the March and May plantings (Table 4.12). In the March planting, sucker size 2 and 3 produced more healthy plants than sucker size 4 and 5. Sucker size 2 had a significantly higher percentage of healthy plants than sucker size 4 and 5. Sucker size 5 had double the percentage of dead plants than sucker size 2, 3 and 4 (Table 4.12). In the May planting, there were more slow growing plants than healthy growing and dead plants overall. Sucker size 3 and 4 had a significantly higher percentage of healthy plants than sucker size 2 (Table 4.12). In the August planting, approximately 80% of the plants were healthy, and no plants died in sucker size 2, 3 and 5 (Table 4.12). Overall, the percentage of wilted plants that were healthy at 6 months after planting was markedly higher in the August planting than in the March and May plantings (Table 4.12).

Table 4.12. Effect of sucker size on wilted plants that were dead, slow growing and healthy in the March, May and August plantings.

Sucker harvesting time after post-harvest $(NH_4)_2SO_4$application	Sucker size	Percentage of plants Dead	Slow growing	Healthy
March planting	2 (largest)	6.2	26.1	67.7
	3	7.7	38.5	53.8
	4	4	56.3	39.7
	5 (smallest)	14.5	40.1	45.4
$LSD_{0.05}$		20.85		
May planting	2	5.6	67.6	15.7
	3	3.7	55	41.3
	4	0	47.2	52.8
	5	5.6	66.5	27.9
$LSD_{0.05}$		25.5		
August planting	2	0	18.2	81.8
	3	0	22.4	77.6
	4	1.2	27.6	71.2
	5	0	17.3	82.7
$LSD_{0.05}$		12.94		

Plants that were planted too deep

Death of plants planted too deep occurred only in the March and May plantings (Table 4.13). The May planting had the highest percentage of slow growing plants while the highest percentage of healthy plants occurred in the August planting. (Table 4.13).

Table 4.13. Proportion of dead, slow growing and healthy plants as a percentage of plants that had been tagged at 2 months as planted too deep in the March, May and August plantings.

	Percentage of plant		
	March planting	May planting	August planting
Dead plants	10.4	17.3	0
Slow growing plants	40.6	56.8	38.1
Healthy plants	49	25.9	61.9
$LSD_{0.05}$	14.19	12.43	5.04

Post-harvest $(NH_4)_2SO_4$ application only had a significant effect on the dead, slow growing and healthy plants that were planted too deep in the March planting (Table 4.14). A higher percentage of dead and slow growing plants occurred where no $(NH_4)_2SO_4$ was applied than in the 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ treatments. The 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application had a significantly higher percentage of healthy plants than where it had not been applied (Table 4.14). Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the dead, slow growing and healthy plants that were planted too deep in the May and August plantings (data not shown)

Table 4.14. Effect of post-harvest $(NH_4)_2SO_4$application on plants planted too deep that were dead, slow growing and healthy, in the March planting.

	Percentage of plants		
$(NH_4)_2SO_4$application rate	Dead	Slow growing	Healthy
0 ton/ha	23.8	54.6	21.6
0.5 ton/ha	5.4	33.4	61.2
1 ton/ha	2.1	34	63.9
$LSD_{0.05}$		24.58	

Sucker size only had a significant effect on the slow growing and healthy plants that were planted too deep in the May planting (Table 4.15).The percentage of slow growing plants was low on larger suckers and increased with a decrease in sucker size. Sucker size 2 and 3 had significantly less slow growing plants and more healthy plants than sucker size 5. Although there was a high percentage of dead plants, sucker size had no significant influence (Table 4.15).

Table 4.15. Effect of sucker size on dead, slow growing and healthy plants in plants planted too deep, in the May planting.

	Percentage of plants		
Sucker size	Dead	Slow growing	Healthy
2 (largest)	18.3	43.7	38
3	14.9	44.9	40.3
4	17	62.5	20.5
5 (smallest)	19	76	5
$LSD_{0.05}$		24.86	

Plants with funnel rot symptom

In the March planting, 78.5% of the plants affected by funnel rot were growing slowly, with only 20.8% healthy and less than 1% dead (Table 4.16). The May and August plantings had a statistically insignificant percentage of plants affected by the funnel rot (data not shown).

Table 4.16. Proportion of dead, slow growing and healthy plants as a percentage of plants that had been tagged at 2 months after planting as plants affected by the funnel rot in the March planting.

	Percentage of plants
	March planting
Dead plants	0.7
Slow growing plants	78.5
Healthy plants	20.8
$LSD_{0.05}$	16.14

At 6 months after planting, most of the plants affected by the funnel rot symptom in the different fertilizer treatments were growing slowly (Table 4.17). Healthy plants were only found in plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ (Table 4.17). Post-harvest $(NH_4)_2SO_4$ application had no significant effect on plants affected by the funnel rot in the May and August plantings (data not shown).

Table 4.17. The effect of post-harvest $(NH_4)_2SO_4$ application on the percentage of dead, slow growing and healthy plants in plants affected by the funnel rot in the March planting.

	Percentage of plants		
	Dead plants	Slow growing plants	Healthy plants
0 ton/ha	0	100	0
0.5 ton/ha	2.1	45.8	43.8
1 ton/ha	0	81.2	18.8
$LSD_{0.05}$		16.14	

Sucker size had no significant effect on the dead, slow growing and healthy plants on the plants affected by the funnel rot symptom in all the plantings (data not shown).

Plants that toppled over

In the May planting, there was a significant difference between the dead plants, slow growing plants and healthy plants, that were affected by toppling over (Table 4.18). The highest percentage of the toppled over plants developed into healthy plants, whilst the plants that died formed the lowest percentage (Table 4.18). There was no significant difference between the dead, slow growing and healthy plants that toppled over in the March and August plantings (data not shown).

Table 4.18. Proportion of dead, slow growing and healthy plants as a percentage of plants that had been tagged at 2 months after planting as plants that toppled over in the May planting.

	Percentage of plants
	May planting
Dead plants	7.4
Slow growing plants	39.8
Healthy plants	52.8
$LSD_{0.05}$	7.34

Post-harvest $(NH_4)_2SO_4$ application and sucker size had no significant effect on the dead, slow growing and healthy plants in the plants that toppled over in all the plantings (data not shown).

Slow growing plants

In the March and August plantings, there was a significant difference ($p < 0.05$) between the dead, slow growing and healthy plants in the plants that were tagged at 2 months after planting as slow growing. In both plantings, the highest percentage of the plants remained slow in growth (Table 4.19). Dead plants formed the lowest percentage (Table 4.19). In the May planting, there was no significant difference between the dead, slow growing and healthy plants (data not shown).

Table 4.19. Proportion of dead, slow growing and healthy plants as a percentage of plants that had been tagged at 2 months after planting as slow growing in the March and August plantings.

	Percentage of plants	
	March planting	August planting
Dead plants	3.3	0
Slow growing plants	62.8	60.8
Healthy plants	33.9	39.2
$LSD_{0.05}$	5.87	4.94

Post-harvest $(NH_4)_2SO_4$ application and sucker size had no significant effect on the dead, slow growing and healthy plants among the plants that were tagged as showing slow growth symptom at 2 months after planting (data not shown).

Plants that were dying back

In the May planting, a high percentage of plants affected by the dying back were growing slowly, and less than 1% of the plants grew into healthy plants (Table 4.20). A very low and insignificant percentage of plants were affected by the dying back symptom in the March and August planting (data not shown).

Table 4.20. Proportion of dead plants, slow growing plants and healthy plants as percentage of plants that had been tagged at 2 months after planting as affected by the dying back symptom in the May planting.

	Percentage of plants
	May planting
Dead plants	30.4
Slow growing plants	68.7
Healthy plants	0.9
$LSD_{0.05}$	11.88

Post-harvest $(NH_4)_2SO_4$ application and sucker size had no significant effect on the dead, slow growing and healthy plants on plants that were affected by the dying back symptom in all the plantings (data not shown).

4.4.3 Mealybug and red mite infestation.

All 3 plantings had low infestations of mealybug and red mite. Sucker size and post-harvest $(NH_4)_2SO_4$ application had no significant effect on mealybug, and red mite population (data not shown).

4.4.4 Leaf analysis

4.4.4.1 Percentage leaf nitrogen, phosphorus and potassium at red bud stage in the March, May and August plantings.

Percentage leaf nitrogen

In the August planting, the plants treated with 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ had a significantly higher percentage ($p < 0.05$) leaf nitrogen than the plants treated with 0 ton/ha post-harvest $(NH_4)_2SO_4$ (Fig. 4.14). Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the percentage leaf nitrogen in the March and May plantings (data not shown).

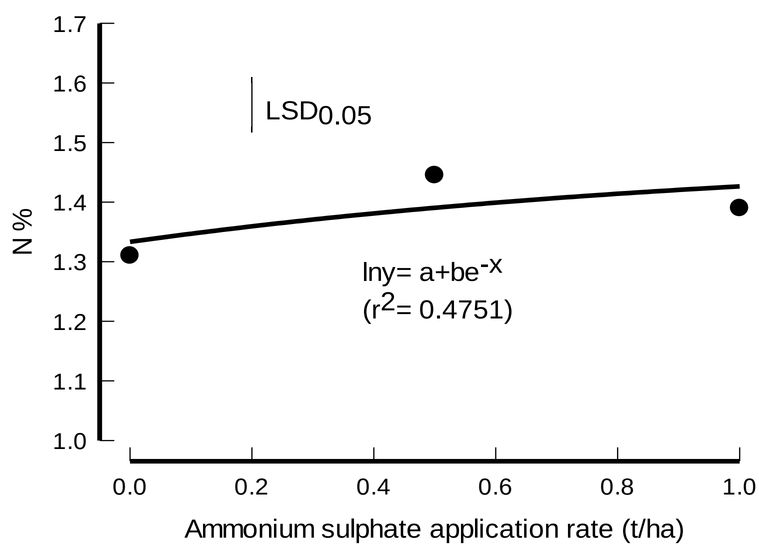


Figure 4.14. Effect of post-harvest $(NH_4)_2SO_4$ application on the percentage leaf nitrogen of plants planted in August. (Data points are means of 3 replications).

Sucker size had a significant effect ($p < 0.05$) on the leaf nitrogen percentage in the March planting (Fig. 4.15). Plants planted from smaller suckers, size 4 and 5, had a significantly higher leaf nitrogen percentage than the plants planted from larger suckers, size 2 and 3 (Fig. 4.15). Sucker size had no significant influence on leaf nitrogen percentage in the May and August plantings at evaluation (data not shown).

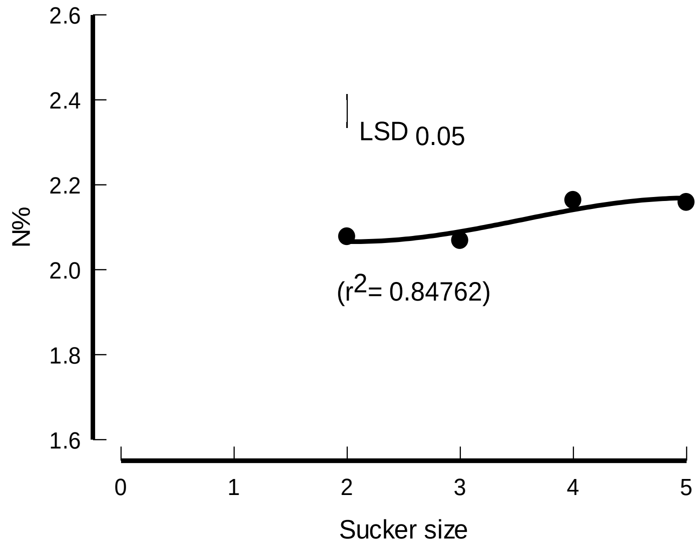


Figure 4.15. Effect of sucker size on the percentage leaf nitrogen in plants of the March planting. (Data points are means of 3 replications).

Percentage leaf phosphorus

Post-harvest $(NH_4)_2SO_4$ application had a significant effect ($p < 0.05$) on the percentage leaf phosphorus in the March, May and August plantings (Fig. 4.16 A, B and C). The plants treated post-harvest with 1 ton/ha $(NH_4)_2SO_4$ had a significantly higher ($p < 0.05$) percentage leaf phosphorus than the plants that had not received post-harvest $(NH_4)_2SO_4$ (Fig. 4.16 A, B and C). There was a positive correlation with a significant difference between percentage leaf phosphorus and post-harvest $(NH_4)_2SO_4$ application rate in the May planting (Fig. 4.16 B).

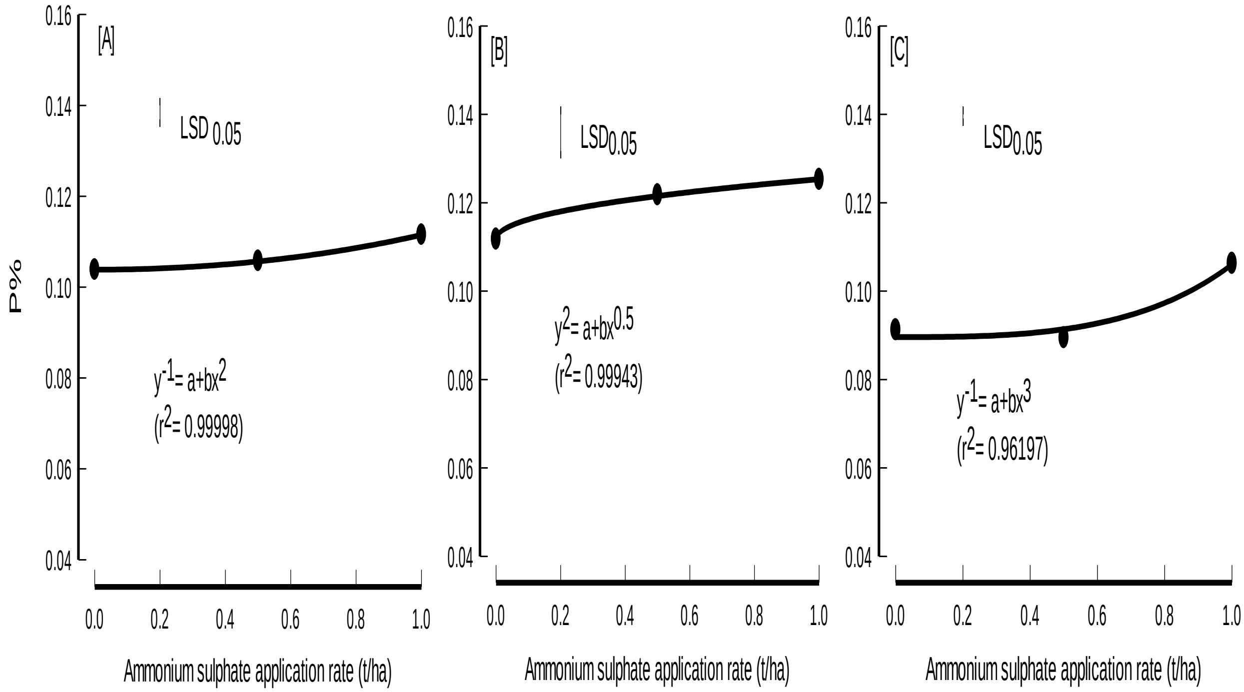


Figure 4.16. Effect of post-harvest $(NH_4)_2SO_4$ application on leaf phosphorus percentage in the March planting [A], May planting [B] and the August planting [C]. (Data points are means of 3 replications).

Sucker size had no significant influence on the leaf phosphorus percentage in all the plantings (data not shown).

Percentage leaf potassium

Post-harvest $(NH_4)_2SO_4$ application had a significant effect ($p < 0.05$) on the percentage leaf potassium in the March and August planting (Fig. 4.17 A and B). The plants treated post-harvest with 1 ton/ha $(NH_4)_2SO_4$ had a significantly higher ($p < 0.05$) leaf potassium percentage than the plants not treated with $(NH_4)_2SO_4$ (Fig. 4.17 A and B). Post-harvest $(NH_4)_2SO_4$ application had no significant influence on the leaf potassium percentage in the March planting (data not shown).

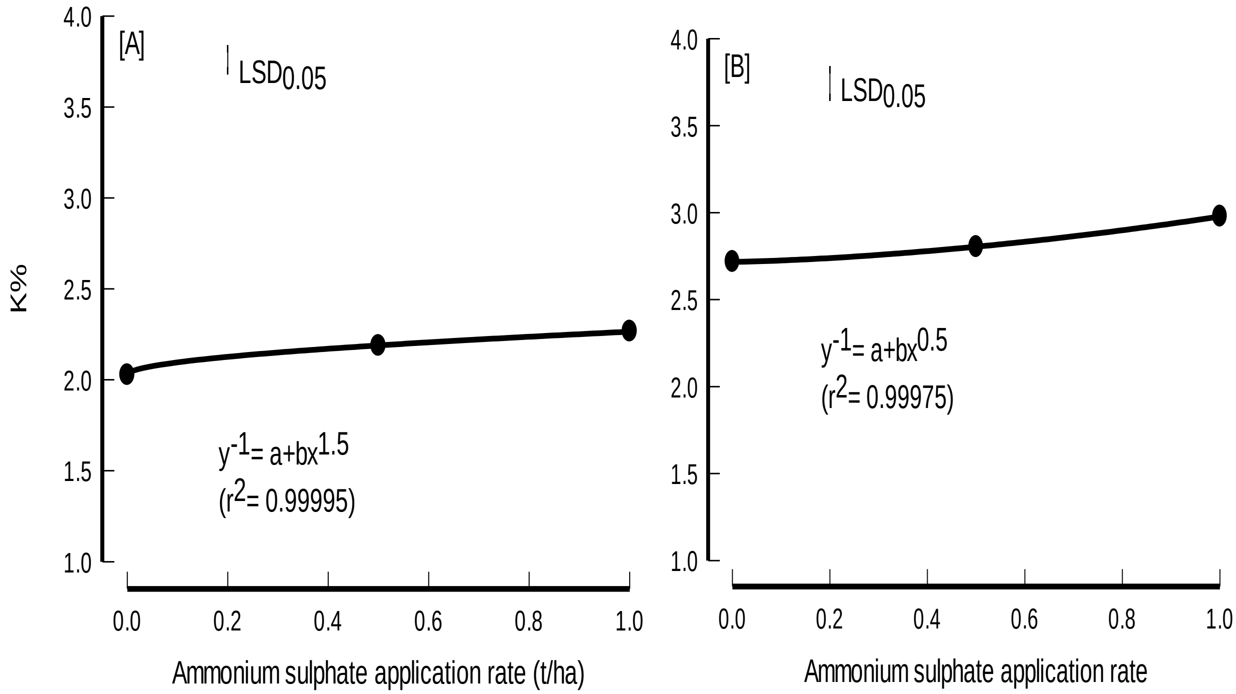


Figure 4.17. Effect of postharvest Post-harvest $(NH_4)_2SO_4$ application on the leaf potassium percentage in the March planting [A] and in the August planting [B]. (Data points are means of 3 replications).

Sucker size had no significant influence on the leaf potassium percentage in all the plantings (data not shown).

4.4.5 The occurrence of natural flowers and the percentage of flowering after flower induction

4.4.5.1 Natural flowering

Effect of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application had no significant effect ($p < 0.05$) on natural flowering of plants from suckers planted in March and May (data not shown). In the August planting, the plants established from suckers that did not receive any post-harvest $(NH_4)_2SO_4$ application had a significantly higher percentage of natural flowers than those established from suckers that received 0.5 or 1 ton/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 4.18).

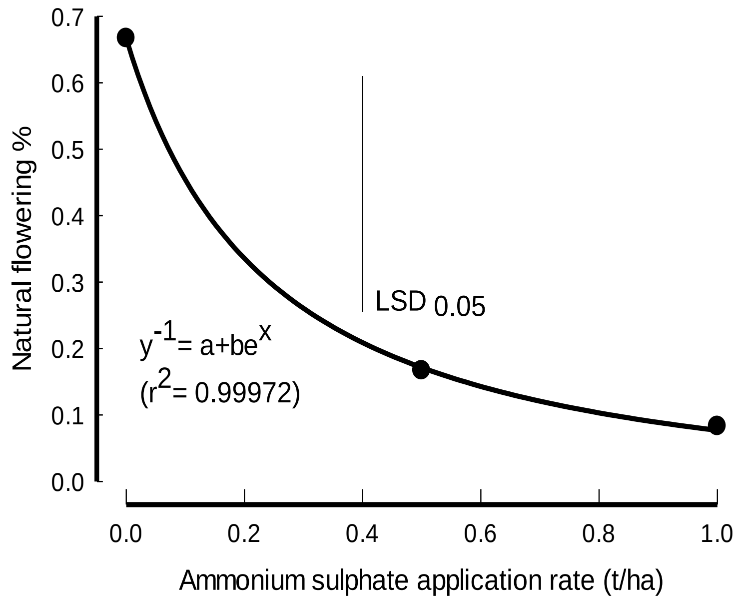


Figure 4.18. Effect of post-harvest $(NH_4)_2SO_4$ application on the average percentage of plants that flowered naturally in the August planting. (Data points are means of 3 replications).

Effect of sucker size

The proportion of plants that flowered naturally correlated positively with increasing sucker size in the March and August plantings (Fig. 4.19). In both of these plantings, differences in the percentage of plant that flowered naturally were markedly larger between size 2 and 3 suckers than they were between progressively smaller sizes (Fig. 4.19). Sucker size did not significantly affect the percentage of plants that flowered naturally in the May planting (data not shown).

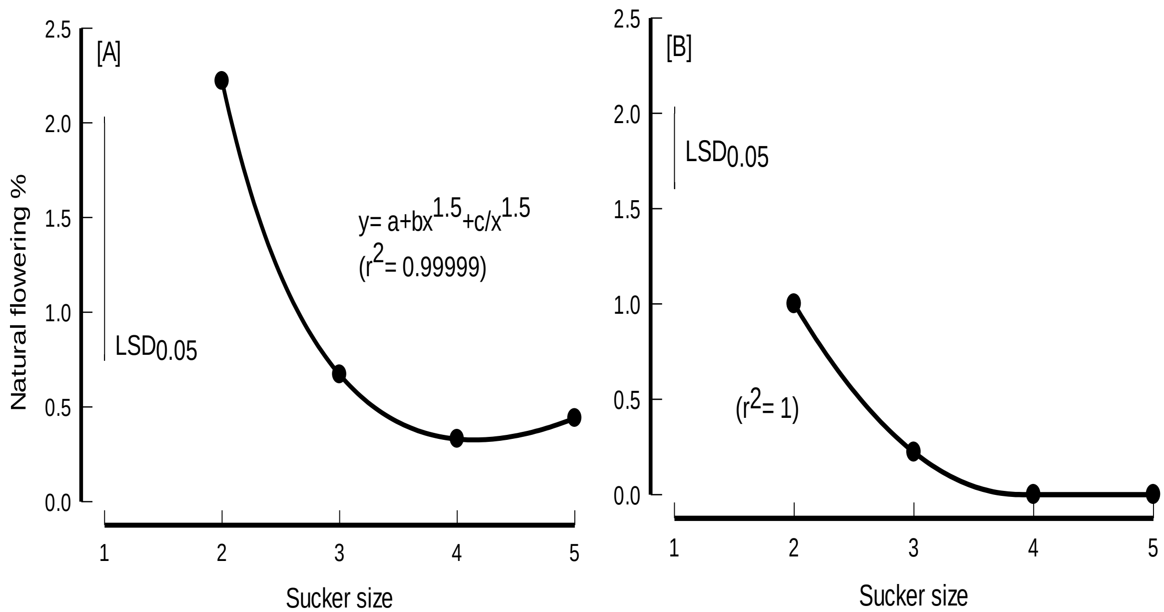


Figure 4.19. Effect of sucker size on natural flowering in the March planting [A] and the August planting [B]. (Data points are means of 3 replications).

Response to flower induction

A small proportion of plants failed to respond to flower induction treatment in both the plants that had mortality symptoms and those that did not (Table 4.21). However, among the 3 plantings, the percentage of plants that failed to flower was significantly higher in the plants that had mortality symptoms in the May and August plantings (Table 4.21). In the March planting there was no significant difference in the percentage of plants that failed to flower between the plants affected by the mortality symptoms and those not affected by the plant mortality symptoms. The percentage of plants that failed to flower was highest in the March planting in both categories (Table 4.21).

Table 4.21. The average percentage of plants that failed to flower which was affected by mortality symptoms and those that failed to flower that were not affected by mortality symptoms in the March, May and August plantings.

	Flowering failure percentage		
	Plant with mortality symptoms	Plant free of mortality symptoms	$LSD_{0.05}$
March planting	7.39	8.53	NS
May planting	4.69	1.33	1.72
August planting	5.39	2.17	1.59
Total percentage	17.47	12.03	

Effect of time of planting

In the March planting, wilted plants had the highest percentage of plants that failed to respond to flower induction followed by plants planted too deep and those with funnel rot (Table 4.22). In the May planting, plants affected by dying back and plants planted too deep, had a significantly higher percentage of plants that failed to flower than in the other mortality symptom categories (Table 4.22). The highest percentage of plants that failed to produce flowers in response to induction in the August planting was observed in plants planted too deep and in the plants that toppled over (Table 4.22).

Table 4.22. Percentages of plants in 6 mortality symptom categories that did not respond to flower induction.

	Percentage of affected plants		
Plant mortality Symptom	March planting	May planting	August planting
Wilted	3.11	0.28	0.56
Too deep	1.92	1.5	2.17
Funnel rot	1.67	0.17	0.08
Toppled over	0.17	0.53	1.19
Slow growth	0.44	0.39	0.92
Dying back	0.08	1.83	0.47
Total% of plants not flowering	7.39	4.7	5.39
$LSD_{0.05}$	0.63	0.82	0.53

Effects of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application had no significant influence ($p < 0.05$) on flowering failure of the plants planted too deep, plants affected by funnel rot, plants that toppled over, slow growing plants and plants that were dying back, in all the 3 plantings (data not shown). Also, post-harvest (NH4)2S04 application did not affect the flowering response of plants with wilting symptoms in the May and August plantings (data not shown). However, in the March planting, there was a negative correlation between post-harvest $(NH_4)_2S0_4$ application rate and the percentage of plants that did not respond to flower induction in the wilted symptoms category (Fig. 4.20). Additionally, the percentage of wilted plants that failed to flower in response to flower induction decreased significantly ($p < 0.05$) with each increase in post-harvest $(NH_4)_2S0_4$ application rate (Fig. 4.20).

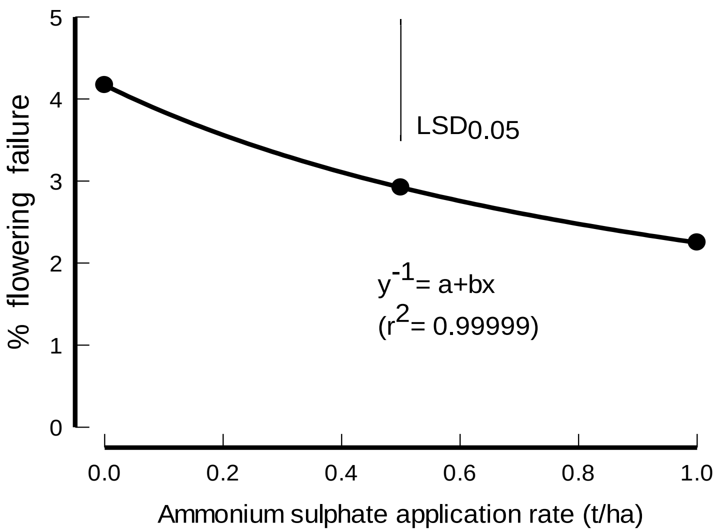


Figure 4.20. Effect of post-harvest $(NH_4)_2S0_4$ application on the percentage wilted plants that failed to respond to flower induction in the March planting. (Data points are means of 3 replications).

Effect of sucker size

Sucker size had a significant influence ($p < 0.05$) on flowering response in plants with the following categories of mortality symptoms (data not shown): plants planted too deep, plants with funnel rot symptom and toppled over plants.

Among the plants that were planted too deep, the proportions of plants that failed to respond to flower induction were highly, but negatively correlated with sucker size, irrespective of the planting time (Fig. 4.21). Thus, in all planting, plants established from larger sucker sizes had a lower percentage of plants that failed to flower compared to plants established from the smaller sucker sizes (Fig. 4.21).

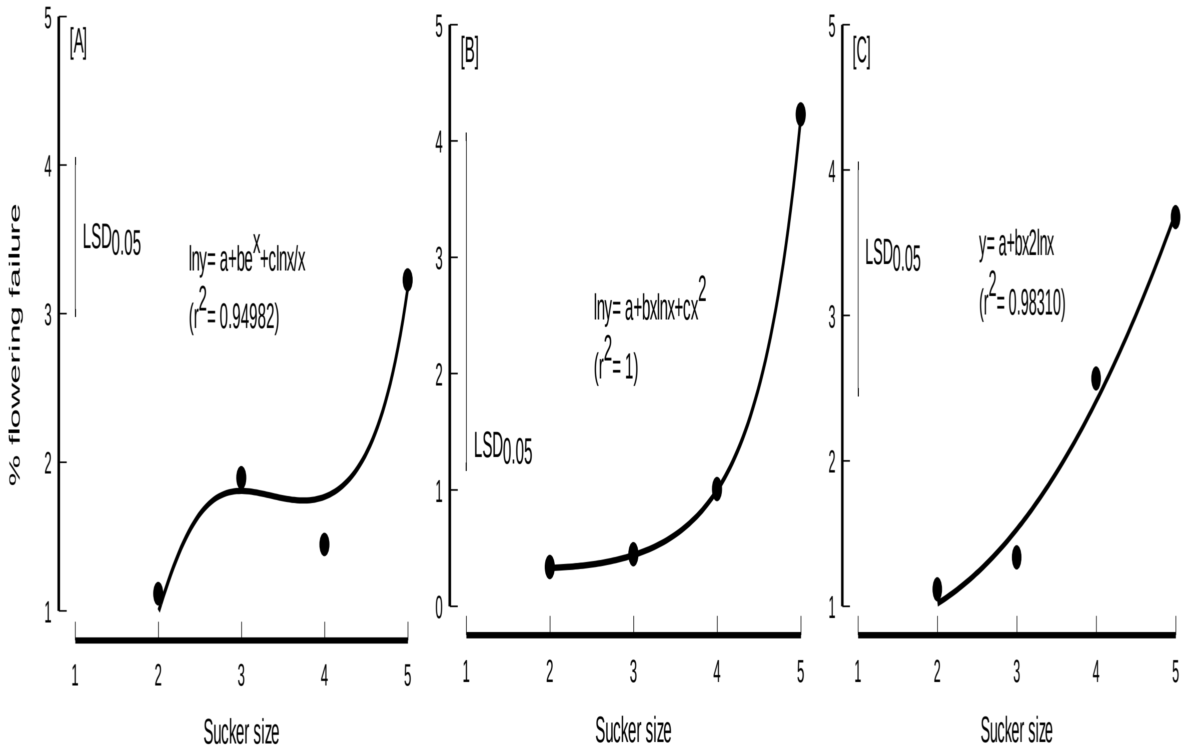


Figure 4.21. Effect of sucker size on proportion of the plants planted too deep that failed to respond to flower induction in the March planting [A], May planting [B] and the August planting [C]. (Data points are means of 3 replications).

In plants that had funnel rot symptoms, sucker size significantly affected flowering only in the March planting, in which the percentage of plants that did not respond to flower induction decreased linearly and significantly with a decrease in suckers size (Fig. 4.22).

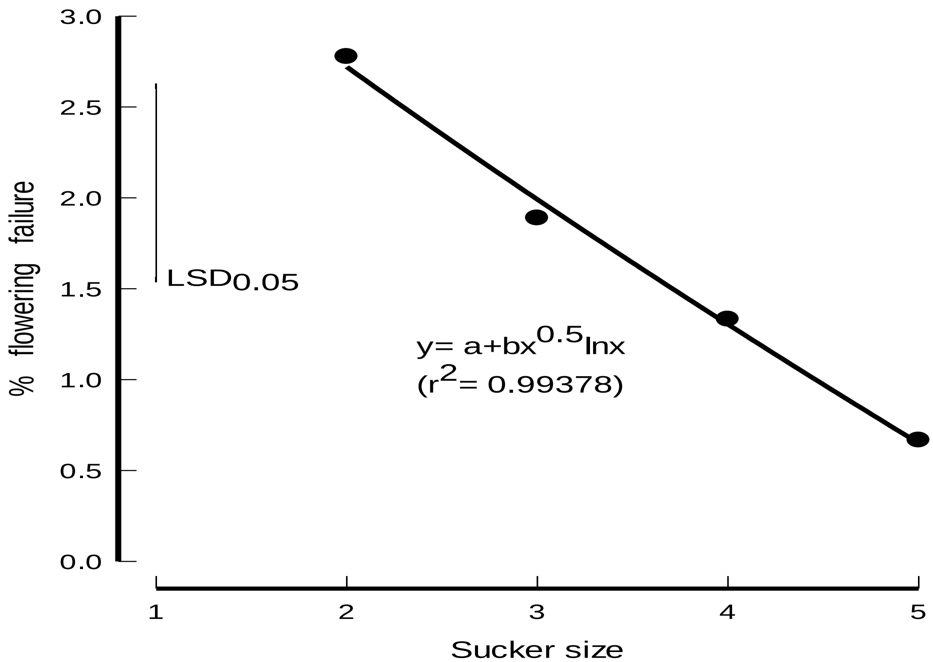


Figure 4.22. Effect of sucker size on percentage of plants in the funnel rot symptom, category, which failed to respond to flower induction in the March planting. (Data points are means of 3 replications).

In plant that toppled over, there was a positive correlation between sucker size and the percentage of flowering failure in the May planting only. Plants established from sucker size 2 had a low percentage of flowering failure, and the percentage of flowering failure increased with smaller sucker sizes (Fig. 4.23). Sucker size had no significant influence ($p < 0.05$) on flowering failure of the plants that toppled over, in the March and August plantings (data not shown).

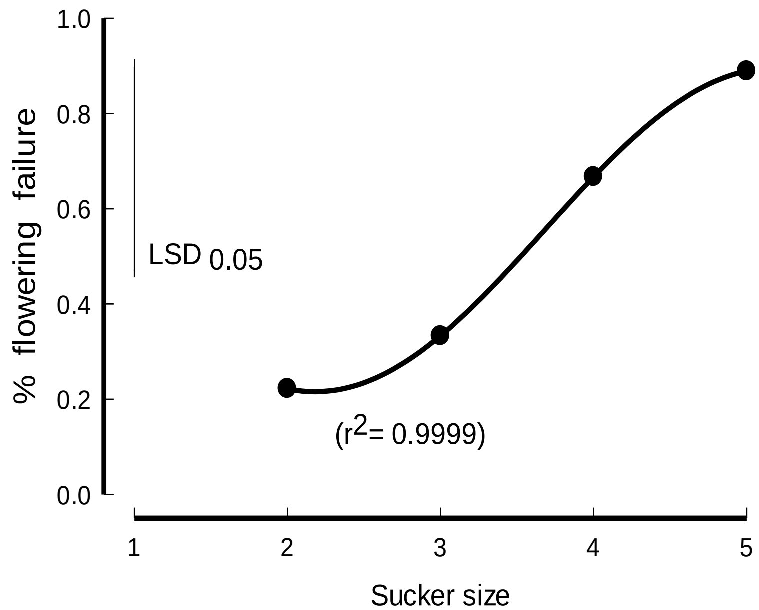


Figure 4.23. Effect of sucker size on the percentage of toppled over plants that failed to respond to flower induction in the May planting. (Data points are means of 3 replications).

4.4.6 Fruit yield (t/ha) and fruit quality at harvest as well as at post harvest in the March, May and August planting.

4.4.6.1 Actual fruit yield

Effect of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application during sucker production had no significant effect on the actual fruit yield in any of the plantings (Table 4.23). There was however a tendency for average actual fruit yield to be highest in the 1 ton/ha post-harvest $(NH_4)_2SO_4$ application in the March and August plantings and in all plant sizes, except for plant size 2 in the August planting (Table 4.23) .

Effect of sucker size

Sucker size significantly affected the actual fruit yield in all the 3 plantings, with the highest fruit yield being recorded in plants established from sucker size 2 and the lowest yield in plants established from sucker size 5.

Table 4.23. The interaction between post-harvest $(NH_4)_2SO_4$ application rate, and sucker size on actual fruit yield in the March, May and August plantings

$(NH_4)_2SO_4$ application rate t/ ha	Sucker size	Fuit yield in March planting (t/ha)	$(NH_4)_2SO_4$ application rate t/ ha	Sucker size	Fuit yield in May planting (t/ha)	$(NH_4)_2SO_4$ application rate t/ ha	Sucker size	Fuit yield in August planting (t/ha)
0	2	76±2.43 de	0	2	88±3.64 de	0	2	62±0.560 f
0.5	2	75±3.13 de	0.5	2	85±3.07 de	0.5	2	55±1.159 def
1	2	82±3.34 e	1	2	91±3.25 e	1	2	62±0.503 ef
0	3	62±6.37 abc	0	3	83±3.05 cde	0	3	49±3.143 cd
0.5	3	69±1.49 cd	0.5	3	80±4.90 bcd	0.5	3	54±4.637 de
1	3	72±4.09 cde	1	3	79±1.30 bcd	1	3	59±2.980 ef
0	4	66±4.07 abcd	0	4	73±1.42 b	0	4	44±2.334 bc
0.5	4	72±2.65 cde	0.5	4	78±5.27 bcd	0.5	4	45±5.006 bc
1	4	68±4.10 bcd	1	4	74±5.45 bc	1	4	46±3.626 c
0	5	58±0.21 a	0	5	50±2.13 a	0	5	35±1.301 a
0.5	5	59±4.32 ab	0.5	5	57±3.29 a	0.5	5	37±1.677 ab
1	5	62±0.79 abc	1	5	49±1.66 a	1	5	35±2.362 a

Means followed by the same letter within a column do not differ significantly ($p \leq 0.05$)

In the March and August planting, the 1 ton/ha post-harvest $(NH_4)_2SO_4$ application rate gave a higher net income/ha of fruit than the 0.5 ton/ha and 0 ton/ha post-harvest $(NH_4)_2SO_4$ application rate (Table 4.24). The 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ application rate had a higher net income/ha of fruit, while the lowest net income/ha was in the1 1 ton/ha post-harvest $(NH_4)_2SO_4$ application rate (Table 4.24).

Table 4.24. Yield of fruit and cost of applying post-harvest $(NH_4)_2SO_4$.

$(NH_4)_2SO_4$ application rate (t/ha)	Time of planting	Fruit yield (t/ha)	Cost of $(NH_4)_2SO_4$ R/ha	Gross income of fruit/ha (R3082.22/ton)	Net income of fruit/ha in Rands
0	March	65.54	0	202008.7	202008.70
0	May	69.34	0	213721.4	213721.40
0	August	47.54	0	146528.7	146528.70
0.5	March	68.41	1 750	210854.7	209104.70
0.5	May	71.17	1 750	219361.6	217611.60
0.5	August	47.48	1 750	146343.8	144593.80
1	March	71.01	3 500	218868.4	215368.40
1	May	67.87	3 500	209190.3	205690.30
1	August	50.15	3 500	154573.3	151073.30

The average actual fruit yield varied among the March, May and August plantings (Fig. 4.24).There was a positive correlation between sucker size and actual fruit, but the nature of the relationship varied with the time of planting (Fig. 4.24). The actual fruit yield was more responsive to increasing sucker size in the May and August plantings than it was in the March planting (Figure 4.24).

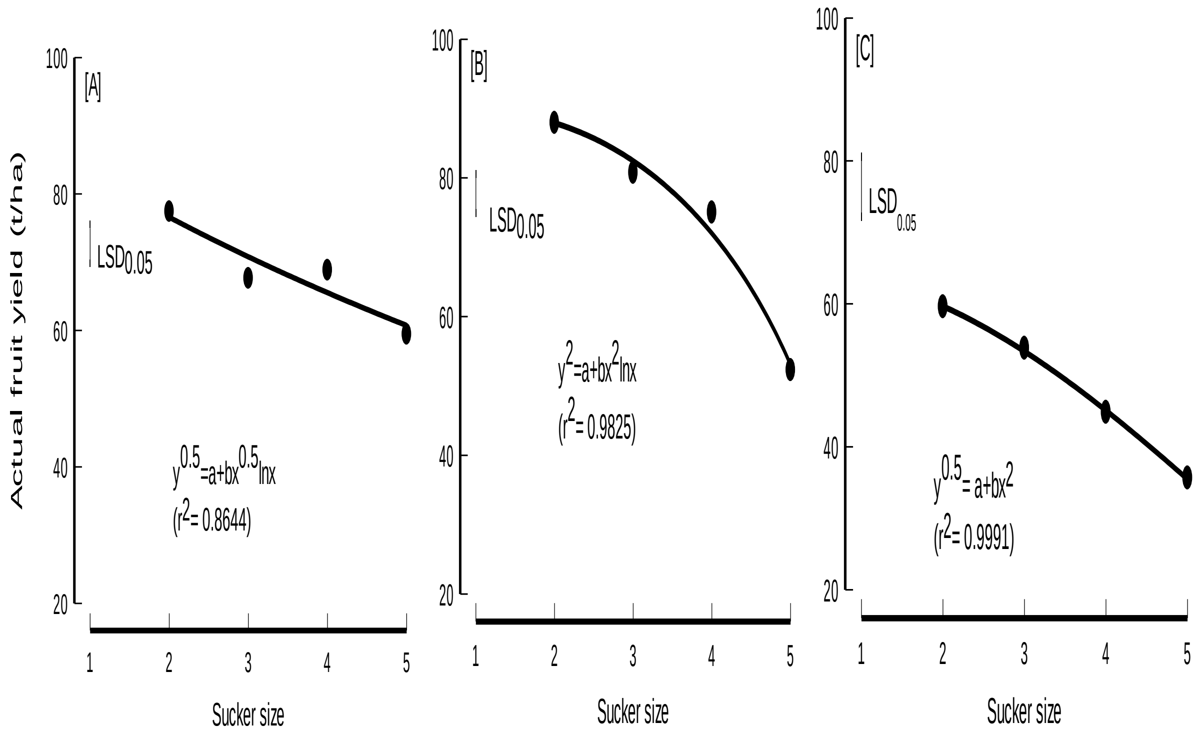


Figure 4.24. Effect of sucker size on the actual fruit yield in the March planting [A], May planting [B] and the August planting [C]. (Data points are means of 3 replications).

4.4.6.2 Potential fruit yield

Effect of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application had no significant effect on the potential fruit yield in the March and May plantings (data not shown). In the August planting, there was a positive correlation between post-harvest $(NH_4)_2SO_4$ application rate and potential fruit yield (Fig. 4.25), in which the potential fruit yield increased linearly with the $(NH_4)_2SO_4$ application rate.

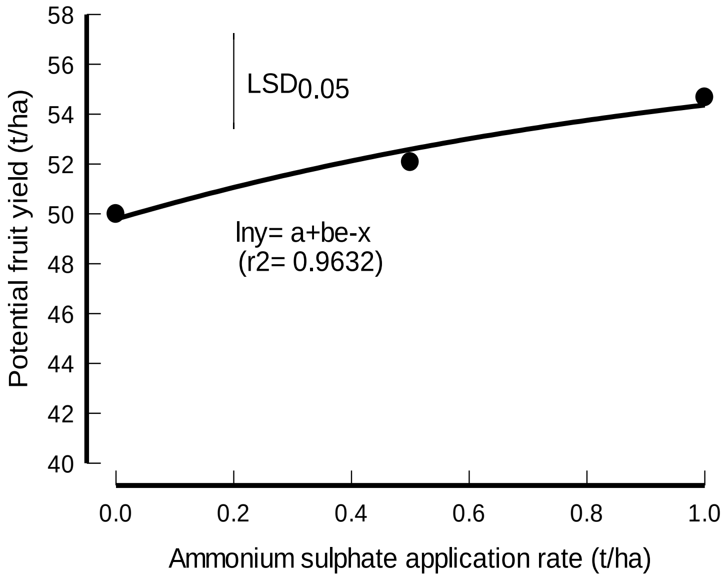


Figure 4.25. Effect of post-harvest $(NH_4)_2SO_4$ application on the potential fruit yield in August planting. (Data points are means of 3 replications).

Effect of sucker size

There was a correlation between sucker size and potential fruit yield in all the three plantings (Fig. 4.26). Generally, the fruit yield increased with increasing sucker size in all the plantings (Fig. 4.26).

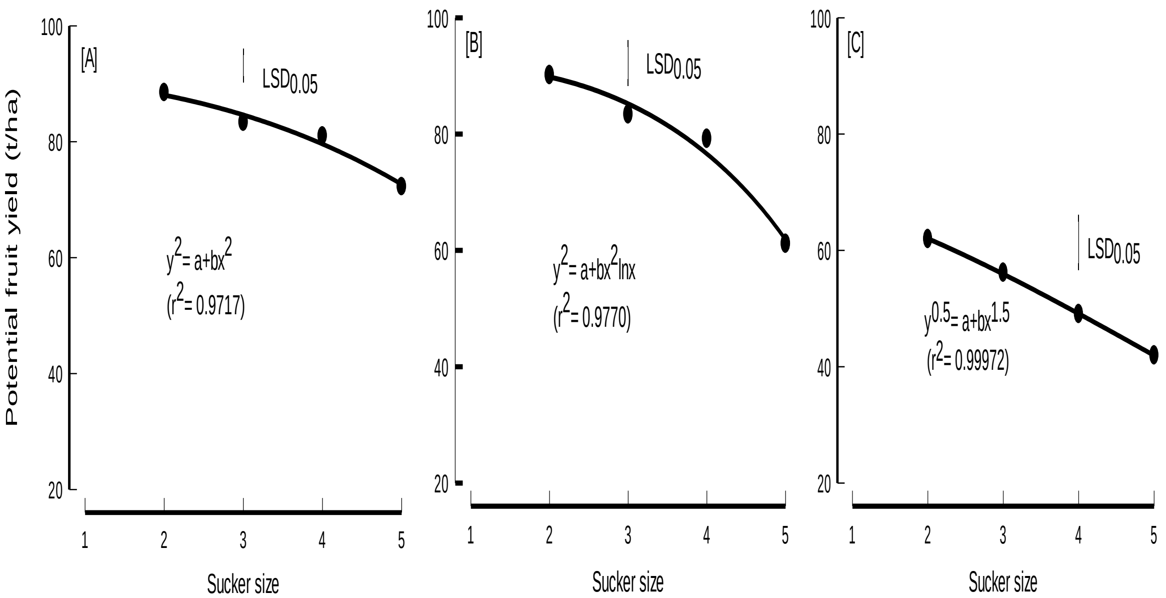


Figure 4.26. Effect of sucker size on the potential fruit yield in the March planting [A], May planting [B] and the August planting [C]. (Data points are means of 3 replications).

The total percentage of plants that did not flower, and the total fruit yield loss was higher in the March planting than in the May and August plantings (Table 4.25). In the March planting there was no remarkable difference between the results of the mortality symptoms and unknown causes (Table 4.25). In the May and August plantings, the mortality symptoms had a higher percentage of plants that did not flower as well as the total fruit yield loss than the unknown causes (Table 4.25). Average fruit yield loss due to plants not flowering was higher in the mortality symptoms than in the unknown causes (Table 4.25).

Table 4.25. Total percentage of plants that did not flower after induction, due to mortality symptoms and unknown causes, and fruit yield loss.

	% of plants not flowering due to:			Fruit yield loss (t/ha) due to:		
Planting time	Mortality symptoms	Unknown causes	Total% non-flowering	Mortality symptoms	Unknown causes	Total fruit yield loss (t/ha)
March	7.39	8.53	15.92	5.94	6.6	12.54
May	4.7	1.33	6.03	3.27	0.93	4.2
August	5.39	2.17	7.56	2.37	0.97	3.34

4.4.6.3 Fruit yield loss due to non-flowering in plants with mortality symptoms

Effect of post-harvest $(NH_4)_2SO_4$ application

Post-harvest $(NH_4)_2SO_4$ application had no significant effect ($p < 0.05$) on fruit yield loss among plants with mortality symptoms in the May planting (data not shown). In the March and August planting, post-harvest $(NH_4)_2SO_4$ application significantly affected the loss of fruit yield among the plants with mortality symptoms, but differently between the 2 plantings (Figure 4.27). In the March planting fruit yield losses decreased linearly and significantly as the post-harvest $(NH_4)_2SO_4$ application rate during sucker development was increased from 0 to 0.5 and 1 t/ha (Fig. 4.27A). In the August planting, plants from suckers treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application had similar fruit losses in fruit yield, and the losses were significantly higher than that for plants from the 0 ton/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 4.27B).

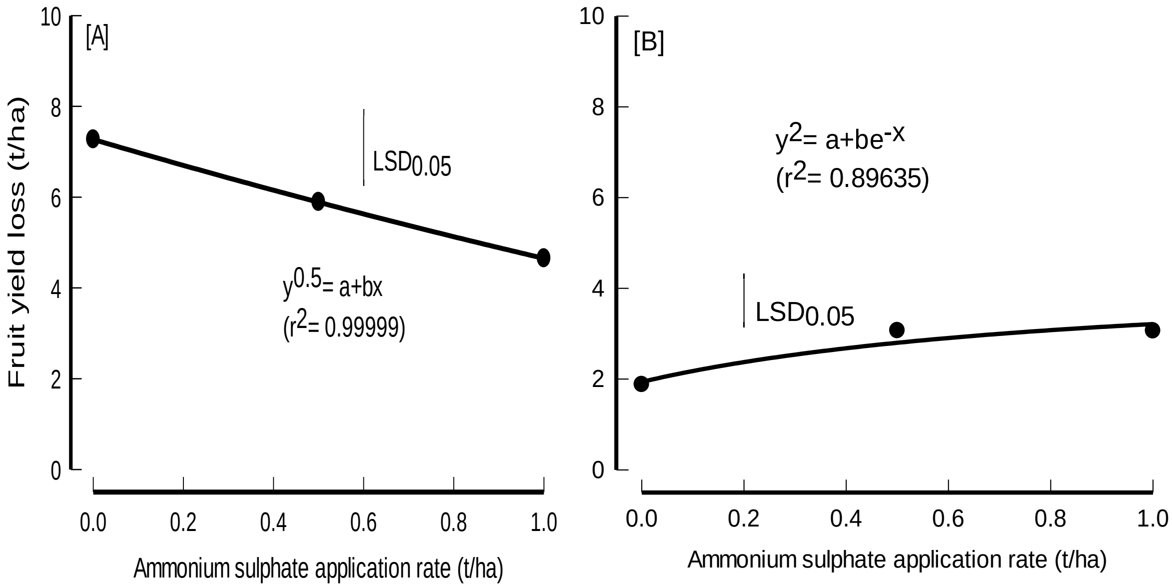


Figure 4.27. Effect of post-harvest $(NH_4)_2SO_4$ application on fruit yield loss in plants affected by the mortality symptoms in the March planting [A] and the August planting [B]. (Data points are means of 3 replications).

Effect of sucker size

In the August planting, there was a positive correlation between sucker size and fruit yield loss among the plants with mortality symptoms (Figure 4.28). Plants established from larger sucker sizes had a significantly lower fruit yield loss than plants established from smaller sucker sizes (Figure 4.28). Sucker size had no significant effect on fruit yield loss in plants with mortality symptoms in the March and May plantings (data not shown).

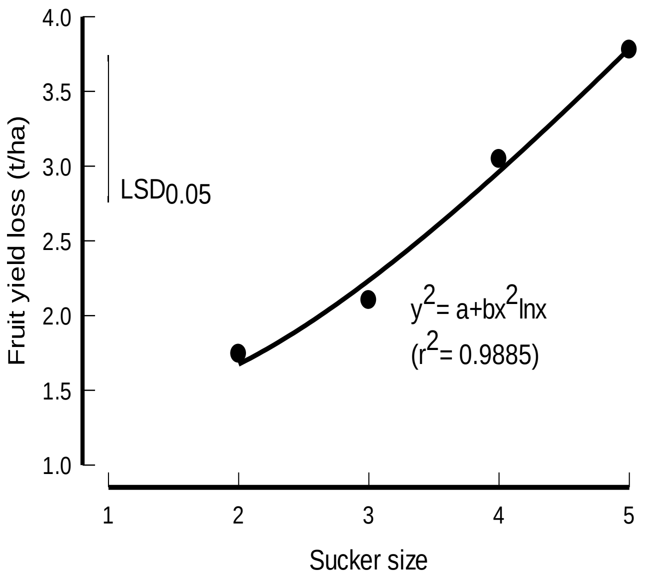


Figure 4.28. Effect of sucker size on fruit yield loss on plants affected by the mortality symptoms in the August planting. (Data points are means of 3 replications).

4.4.6.4 Fruit yield loss due to non- flowering in healthy plants

Effect of post-harvest $(NH_4)_2SO_4$ application

In the August planting, the 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application rates had similar fruit yield loses, and these were significantly higher ($p < 0.05$) than in the 0 ton/ha post-harvest $(NH_4)_2SO_4$ application rate (Fig. 4.29). In the March and May plantings, post-harvest $(NH_4)_2SO_4$ application had no influence on fruit yield loss (data not shown).

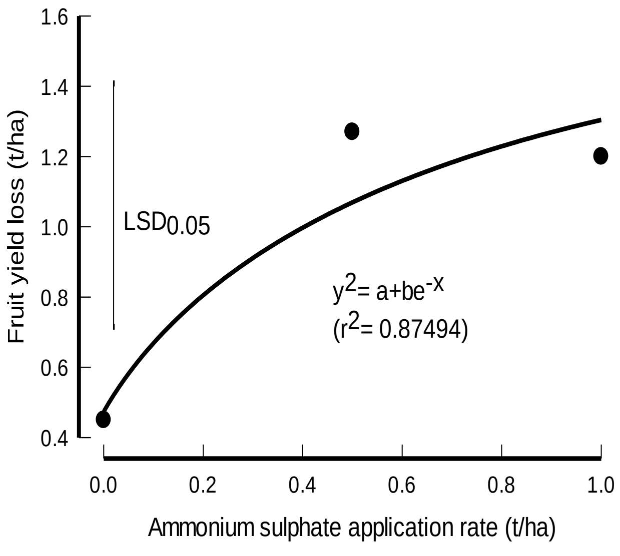


Figure 4.29. Effect of post-harvest $(NH_4)_2SO_4$ application on fruit yield loss in plants that did not have mortality symptoms in the August planting. (Data points are means of 3 replications).

Influence of sucker size

Sucker size had a significant influence on fruit yield loss in the May and August plantings, but not in the March planting. In both the May and August plantings, fruit yield losses were highly correlated with sucker size, showing an increase in fruit yield with decreasing sucker size (Fig. 4.30). The increases in fruit yield loss were significant only in the cases where sucker size decreased below size 3 in the August planting and below size 4 in the May planting (Fig. 4.30).

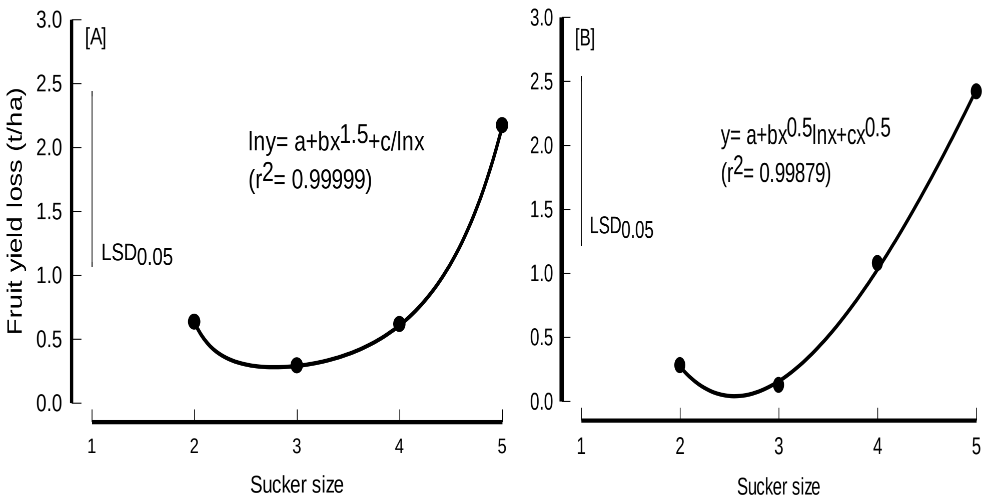


Figure 4.30. Effect of sucker size on fruit yield loss in plants that did not have mortality symptoms in the May planting [A] and August planting [B]. (Data points are means of 3 replications).

4.4.6.5 External and internal fruit quality evaluations

Crown fresh mass

Post-harvest $(NH_4)_2SO_4$ application had no influence on crown fresh mass in the March, May and August plantings (data not shown), whereas sucker size had a significant effect on the crown fresh mass in the May and August plantings (Fig. 4.31). In these plantings, the crown fresh mass was highly and negatively correlated with increasing sucker size, i.e. plants established from larger sucker sizes produced fruit with a lower average crown fresh mass than the fruit produced by plants established from smaller sucker sizes. Sucker size had no influence on crown fresh mass in the March planting (data not shown).

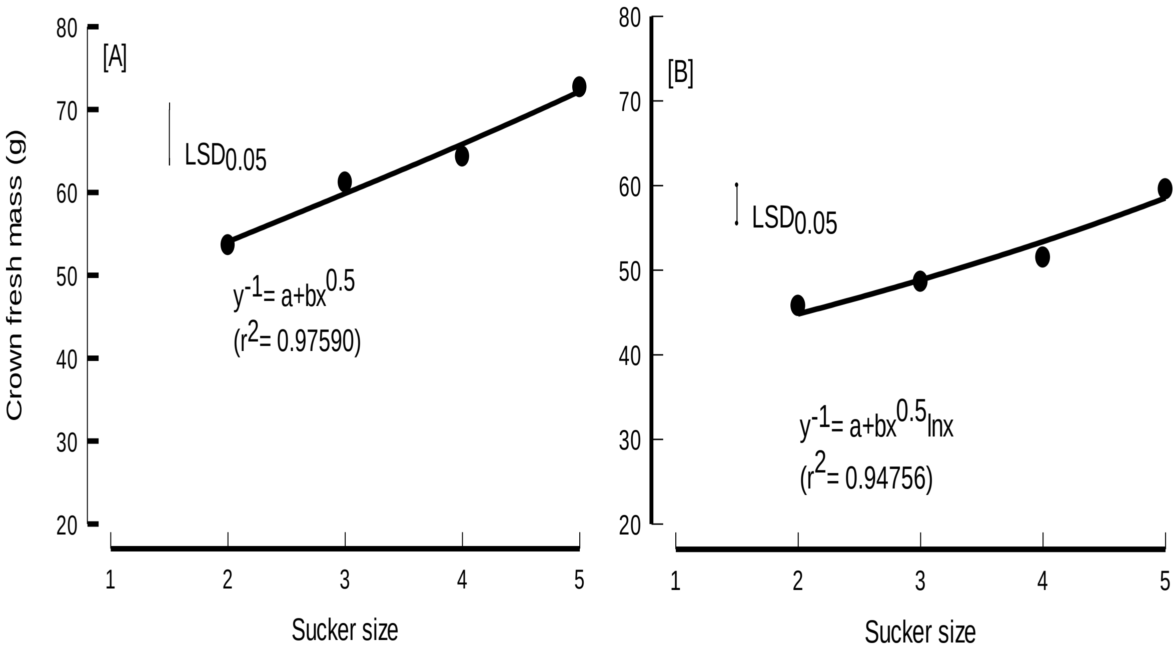


Figure 4.31. Effect of sucker size on the average crown fresh mass at fruit maturity in the May planting [A] and the August planting [B]. (Data points are means of 3 replications).

Fruit length

Post-harvest $(NH_4)_2SO_4$ application had no influence on fruit length in the May and August plantings (data not shown). In the March planting, the fruit in the 0.5 ton/ha post-harvest $(NH_4)_2SO_4$ application rate, had a significantly higher ($p < 0.05$) fruit length than the fruit in the 0 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ application treatment (Fig. 4.32).

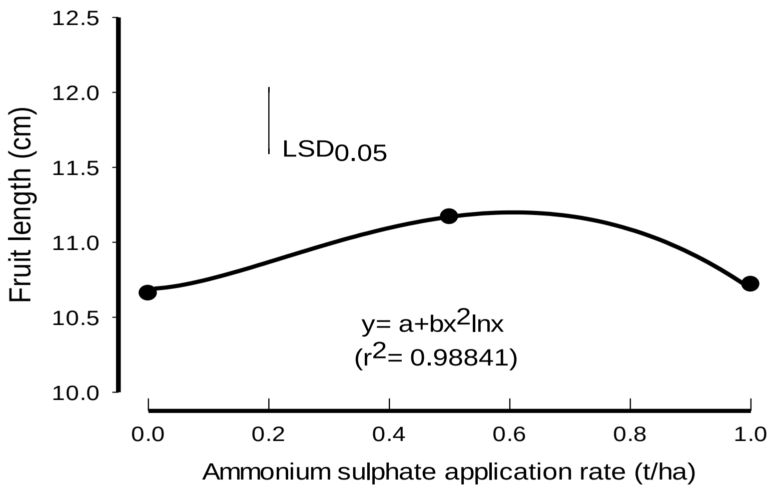


Figure 4.32. Effect of post-harvest $(NH_4)_2SO_4$ application on the average fruit length at fruit maturity in the March planting. (Data points are means of 3 replications).

Plants established from larger sucker sizes produced longer fruit than plants established from smaller sucker sizes in the March planting and May planting (Fig. 4.33 A and B). The highest fruit length 11.4 and 11cm respectively was in sucker size 2, while the lowest crown fresh mass 10.4 and 9.8cm respectively was in sucker size 5 (Fig. 4.33 A and B). Sucker size had no influence on the fruit length, in the August planting (data not shown).

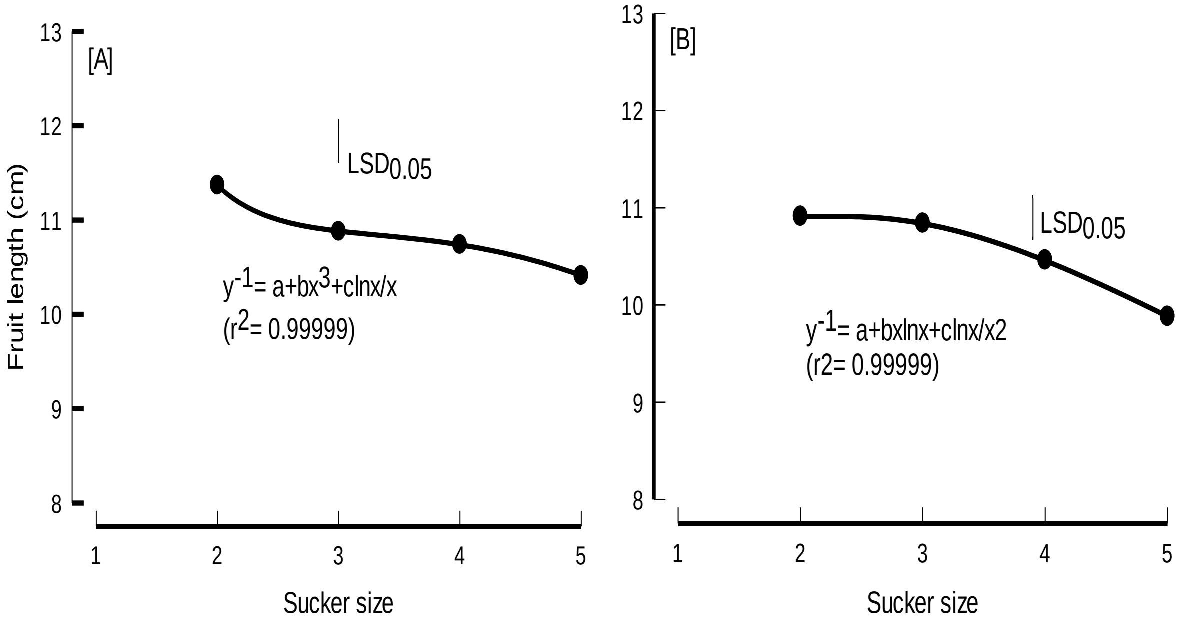


Figure 4.33. Effect of sucker size on the average fruit length at fruit maturity in [A] the March and [B] May plantings. (Data points are means of 3 replications).

Number of fruitlets per fruit spiral

Post-harvest $(NH_4)_2SO_4$ application had no significant influence on the number of fruitlet spirals in plants planted in all the 3 plantings (data not shown).

There was a positive correlation between sucker size and the number of fruitlets per fruit spiral in all the 3 plantings (Fig. 4.34). In each of the plantings, the highest number of fruitlets per fruit spiral were in sucker size 2, and decreased linearly with decreasing sucker size (Fig. 4.34).

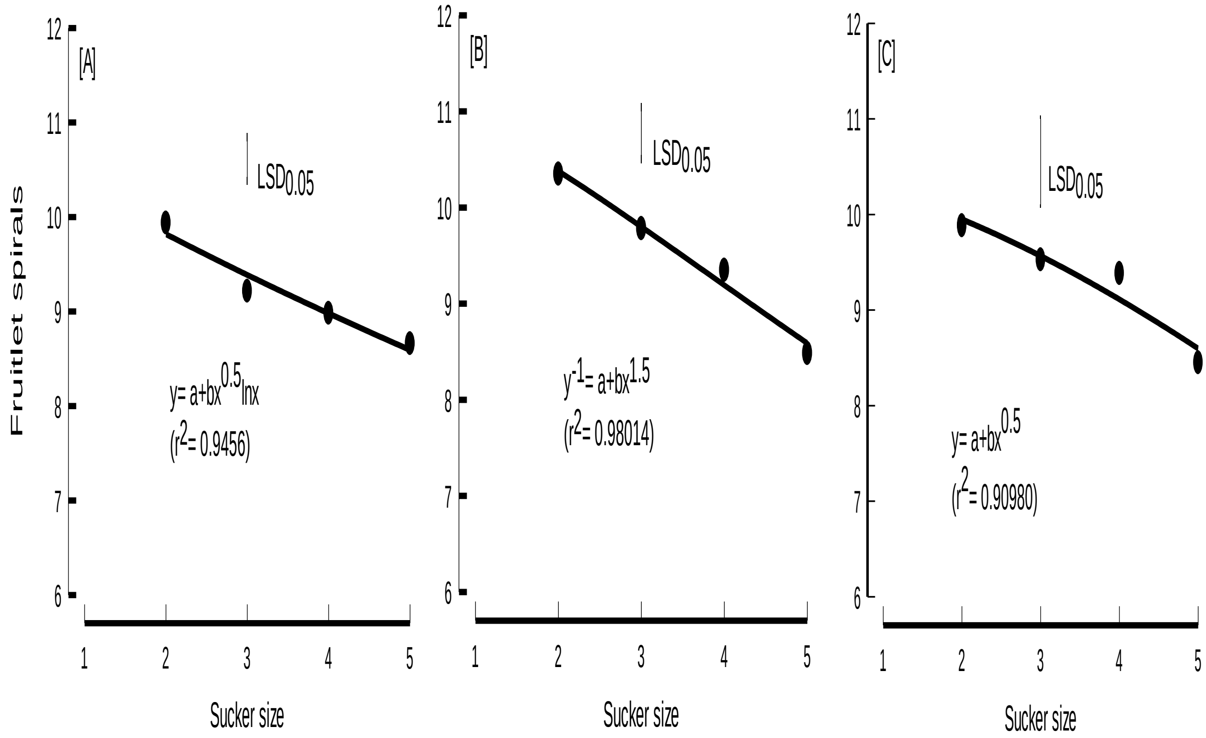


Figure 4.34. Effect of sucker size on the number of fruitlets per fruit spiral at fruit maturity in March [A], May [B] and August plantings [C]. (Data points are means of 3 replications).

Inter-fruitlet cracking

Inter-fruitlet cracking was significantly affected by the post-harvest $(NH_4)_2SO_4$ application rate only in the August planting, in which it increased linearly with increasing post-harvest $(NH_4)_2SO_4$ application rate (Fig. 4.35). The increases in inter-fruitlet cracking with each increase in the post-harvest $(NH_4)_2SO_4$ application were significant ($p < 0.05$).

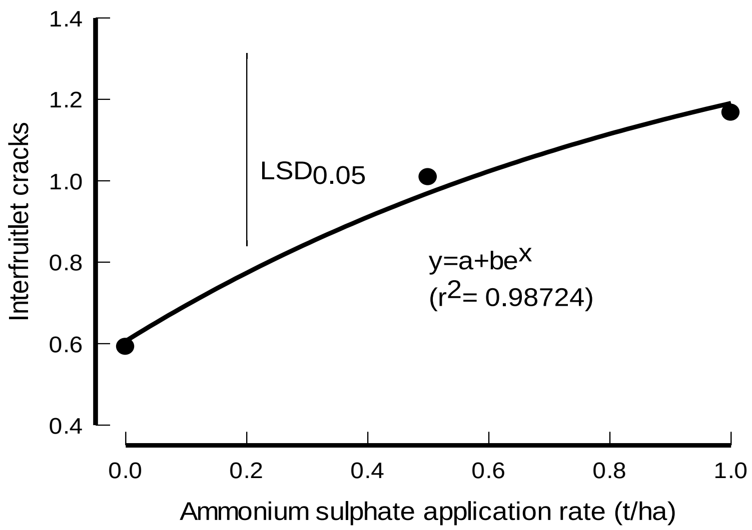


Figure 4.35. Effect of post-harvest $(NH_4)_2SO_4$ application on the average number of fruitlet cracks at fruit maturity in the August planting. (Data points are means of 3 replications).

Sucker size significantly affected the number of interfruitlet cracks in the May planting but not in the March and August plantings. In the May planting, the inter-fruitlet cracking increased in a curvilinear fashion with decreasing sucker size, in which the increases in the number of inter-fruitlet cracks became progressively larger with each decrease in sucker size (Figure 4.36). The number of inter-fruitlet cracks in plants established from sucker size 5 was 4.5 fold higher than in plants established from sucker size 4. Compared with a 1.3 and 1.2 fold difference between sizes 3 and 4 and between 2 and 3, respectively.

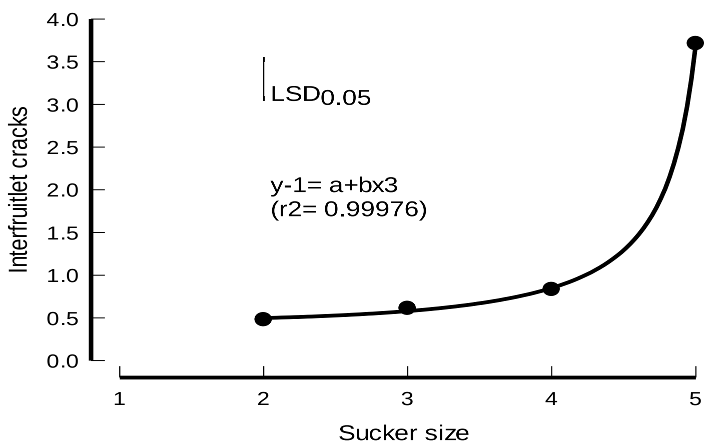


Figure 4.36. Effect of sucker size on the average number of inter-fruitlet cracks at fruit harvest in May planting. (Data points are means of 3 replications).

Winter speckle

Post-harvest $(NH_4)_2SO_4$ application had no significant influence on the average number of winter speckle rings per fruit or percentage fruit covered with winter speckle in the March and August plantings (data not shown), but in the May planting, these 2 parameters were significantly affected by post-harvest $(NH_4)_2SO_4$ application. In relation to the percentage of fruit with winter speckle rings, there was a negative correlation between post-harvest $(NH_4)_2SO_4$ application rate and the percentage fruit covered with winter speckle in the May planting (Fig. 4.37 and 4.38). Furthermore, the average percentage winter speckle occurrence decreased significantly with each increase in post-harvest $(NH_4)_2SO_4$ application rate (Fig. 4.37 and 4.38). The decrease in the percentage of fruit with winter speckle rings as the post-harvest $(NH_4)_2SO_4$ application rate increased was accompanied by decreasing number of winter speckle rings per fruit (Fig. 4.38), The number of winter speckle rings per fruit decreased linearly from 0 to 1 t/ha $(NH_4)_2SO_4$ and the decreases in the winter speckle rings with each increase in the post-harvest $(NH_4)_2SO_4$ application rate were significant.

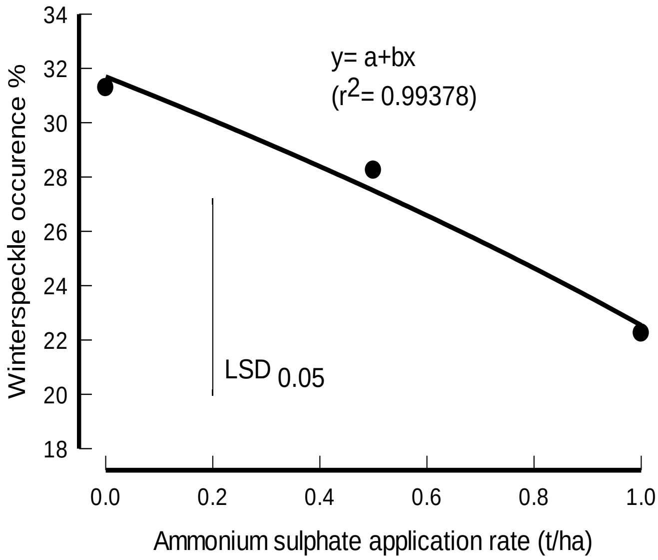


Figure 4.37. Effect of post-harvest $(NH_4)_2SO_4$ application on the average percentage winter speckle occurrence at fruit harvest in the May planting. (Data points are means of 3 replications).

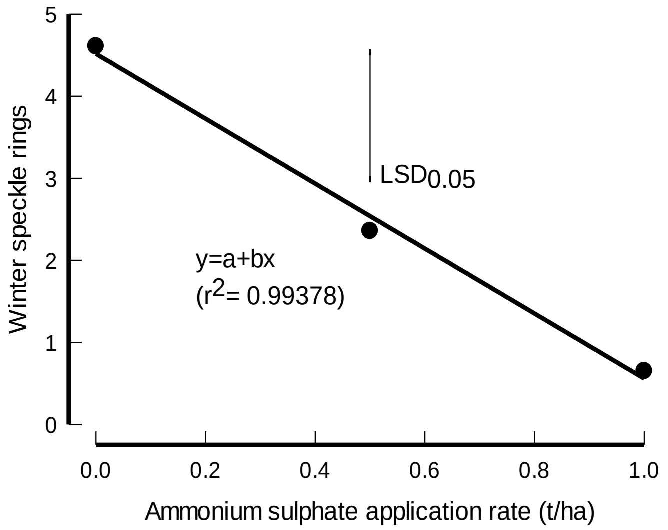


Figure 4.38. Effect of post-harvest $(NH_4)_2SO_4$ application on the number of winter speckle rings at fruit harvest in the May planting. (Data points are means of 3 replications).

Sucker size had no significant effect on the percentage of fruits affected by winter speckle in the March and May planting (data not shown), In the August planting, the number of winter speckle rings per fruit increased with each decrease in sucker size (Fig. 4.39). Increases were markedly larger with decrease in sucker size, less than size 3.

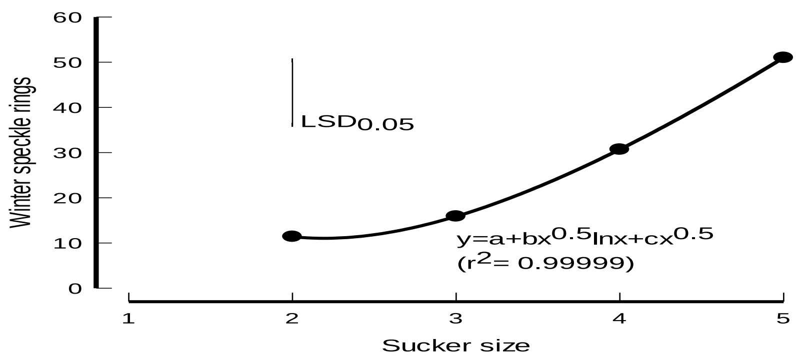


Figure 4.39. Effect of sucker size on average winter speckle infestation percentage in the August planting at fruit harvest. (Data points are means of 3 replications).

Whilst sucker size had no significant influence on the percentage of fruit affected with winter speckle in May, the number of winter speckle rings per fruit were significantly affected by sucker size in the May planting. In this planting, the number of winter speckle rings increased significantly with each decrease in sucker size, producing a highly significant, but negative correlation between the number of winter speckle rings and increasing sucker size (Fig. 4.40). In the March and August plantings sucker size had no significant effect on the number of winter speckle rings per fruit (data not shown).

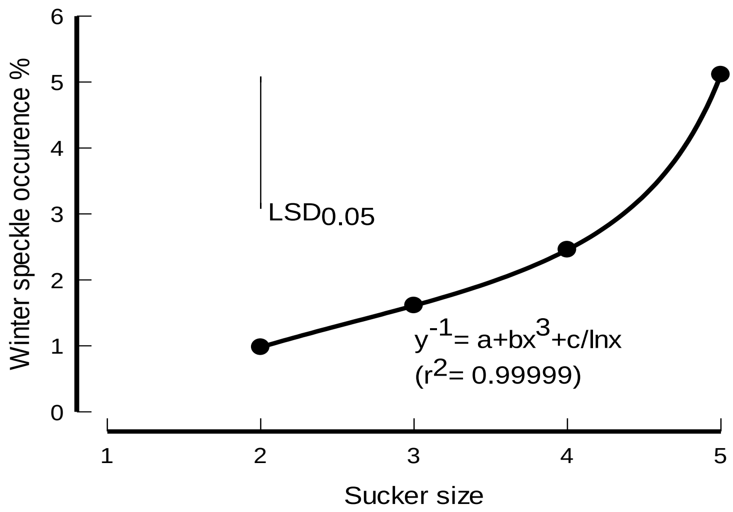


Figure 4.40. Effect of sucker size on the average number of winter speckle rings at fruit harvest in the May planting. (Data points are means of 3 replications).

Evaluation of total soluble solids (TSS)

There was a negative correlation between post-harvest $(NH_4)_2SO_4$ application rate and total soluble solids in the August planting (Fig. 4.41). The highest brix (15.5°) was in the 0 ton/ha fertilizer treatment, while the lowest brix (14.8°) was in the 1 ton/ha fertilizer treatment (Fig. 4.41). Post-harvest $(NH_4)_2SO_4$ application had no significant influence on the total soluble solids in the March and May planting (data not shown).

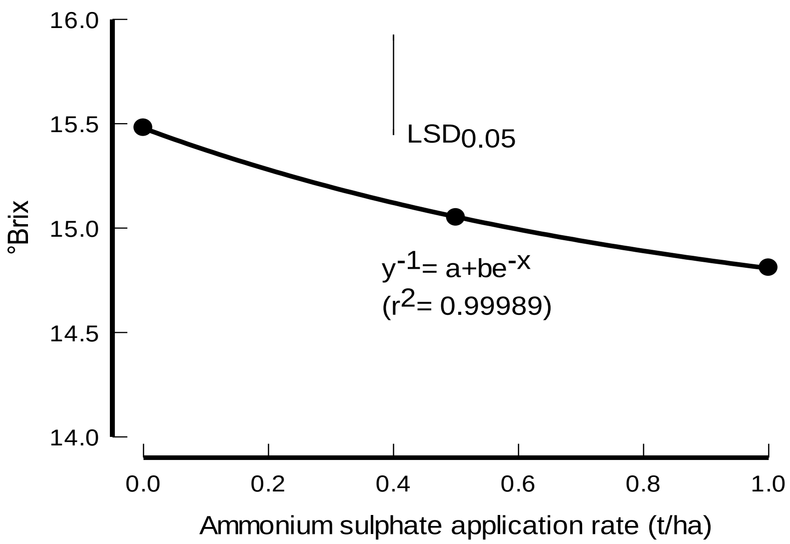


Figure 4.41. Effect of post-harvest $(NH_4)_2SO_4$ application on the average total soluble solids at fruit harvest in the August planting. (Data points are means of 3 replications).

Sucker size had no significant influence on the fruit total soluble solids in the March and August planting (data not shown). In the May planting, the fruit total soluble solids increased linearly with decreasing sucker size from an average of 13.1° in fruit of plants established from sucker size 2 to 15.5 ° in plants established from sucker size 5 (Fig. 4.42). Hence, the fruit total soluble solids were highly negatively correlated with sucker size (Figure 4.42).

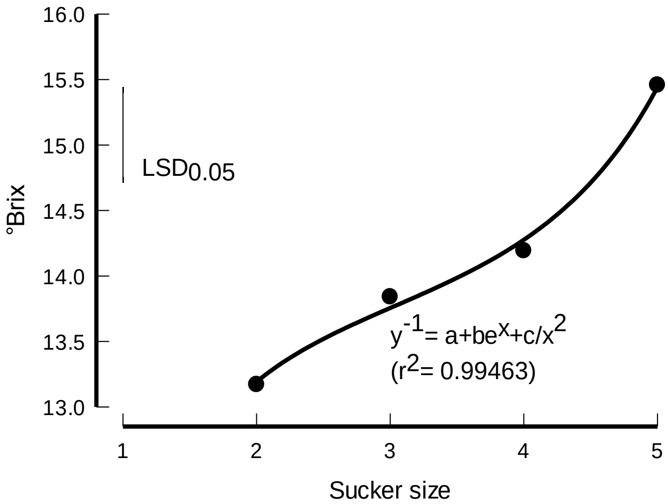


Figure 4.42. Effect of sucker size on the average °Brix at fruit harvest in the May planting. (Data points are means of 3 replications).

4.4.6.6 Post-harvest evaluation of internal fruit quality at 7 and 14 days after fruit harvest

Post-harvest $(NH_4)_2SO_4$ application and sucker size had no significant influence on black spot and nectary duct infection as well as the occurrence of internal browning in all 3 plantings (data not shown). However, the fruit storage duration had a significant influence on the black spot infection in the August planting (Table 4.26), nectary duct infection in the May and August plantings (Table 4.27) and the occurrence of internal browning in the March, May and August plantings which all increased with longer storage periods (Table 4.28).

Table 4.26. Average black spot infection at 7 and 14 days after fruit harvest in the August planting

Days after fruit harvest	Black spot
7	0.583
14	1.133
$LSD_{0.05}$	0.307

Table 4.27. Average nectary duct infection at 7 and 14 days after fruit harvest in the May and August plantings

	Nectary duct	
Days after fruit harvest	May planting	August planting
7	0.4	0.389
14	0.706	0.706
LSD $_{0.05}$	0.2502	0.2679

Table 4.28. Average internal browning infection at 7 and 14 days after fruit harvest in the March planting, May planting and August planting

	Internal browning		
Days after fruit harvest	March planting	May planting	August planting
7	0.37	0.00	0.00
14	1.16	0.58	0.78
LSD $_{0.05}$	0.22	0.20	0.15

4.4.7 Post-harvest sucker yield at 8 months after fruit harvest in the March and May planting.

4.4.7.1 Sucker yield of healthy plants and plants that were wilted and those planted too deep

Effect of health condition of the plant on sucker yield

In the March and May plantings, the condition of the mother plant had a significant ($p < 0.05$) effect on the number of suckers produced (Fig. 4.43 A and B). Healthy plants produced a significantly higher ($p < 0.05$) number of plantable suckers than the plants that were planted too deep and those that were wilted (Fig. 4.43 A and B). There was no significant difference on the number of plantable suckers between the plants planted too deep and the wilted plants.

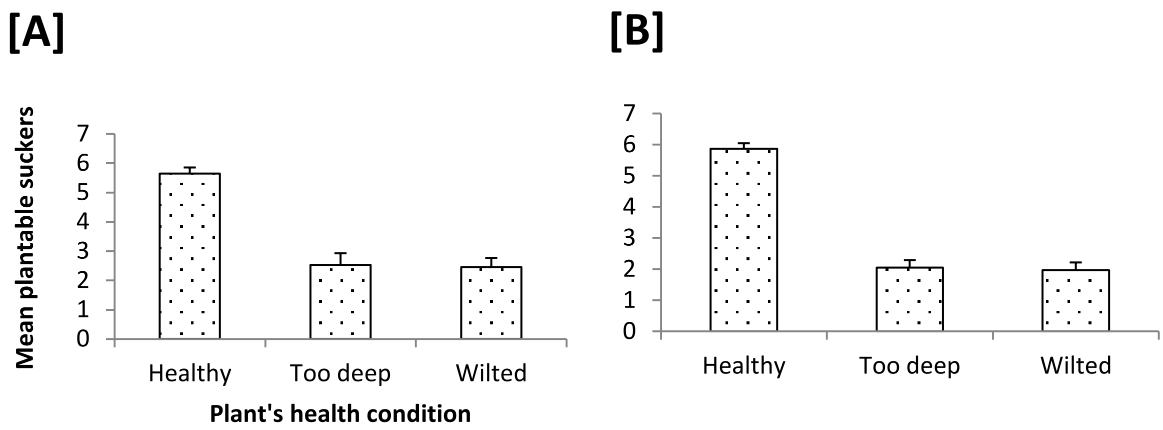


Figure 4.43. Effect of plant's health condition on the number of plantable suckers per plant in the March planting [A] and May planting [B] at 8 months after fruit harvest.

Effect of planting sucker size of mother plant on sucker yield

There was a positive correlation between sucker size and the number of plantable suckers produced by healthy plants in the May planting (Fig. 4.44). The production of plantable suckers decreased linearly with decreasing sucker size of the mother plant from 4.4 per plant in plants established from sucker size 2 to 3.2 in plants established from sucker size 5 (Fig. 4.44). Sucker size had no significant effect on the number of suckers produced by healthy plants in the March planting nor by plants affected by the mortality symptoms in the May and March plantings (data not shown).

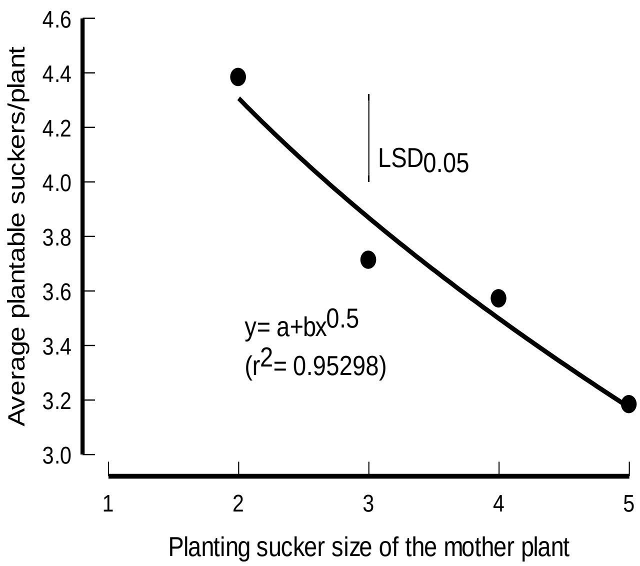


Figure 4.44. Effect of sucker size on the number of plantable suckers in the May planting at 8 months after fruit harvest. (Data points are means of 3 replicates).

Interaction between post-harvest $(NH_4)_2SO_4$ application and planting sucker size of mother plant

A significant interaction effect was observed between post-harvest $(NH_4)_2SO_4$ application and sucker size, on the number of plantable suckers produced in the May planting (Fig. 4.45). The highest number of plantable suckers (5 per plant) was observed in plant size 2 in plants treated with 0.5 t/ha post-harvest $(NH_4)_2SO_4$ application. The lowest number of plantable suckers (2.4 per plant) was observed in plant size 5 in plants treated with 0.5 t/ha post-harvest $(NH_4)_2SO_4$ application (Fig. 4.5).

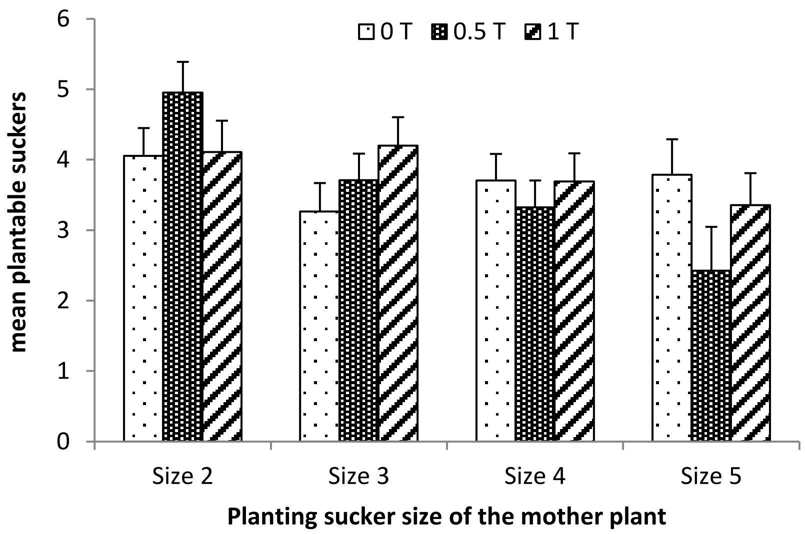


Figure 4.45. Interaction effect between planting sucker size of the mother plant and post-harvest $(NH_4)_2SO_4$ application rate on production of plantable suckers/plant in the May planting at 8 months after fruit harvest. (0T = 0 t/ha $(NH_4)_2SO_4$, 0.5T= 0.5 t/ha$(NH_4)_2SO_4$ and 1T= 1 t/ha $(NH_4)_2SO_4$).

4.4.7.2 Fresh mass of plantable suckers

Effect of the plant's health condition

In both the March and May plantings, the healthy plants produced significantly heavier ($p < 0.05$) suckers than the plants planted too deep and those that were wilted (Fig. 4.46). The wilted plants had a significantly higher ($p < 0.05$) sucker fresh mass than the plants that were planted too deep in both plantings (Fig. 4.46).

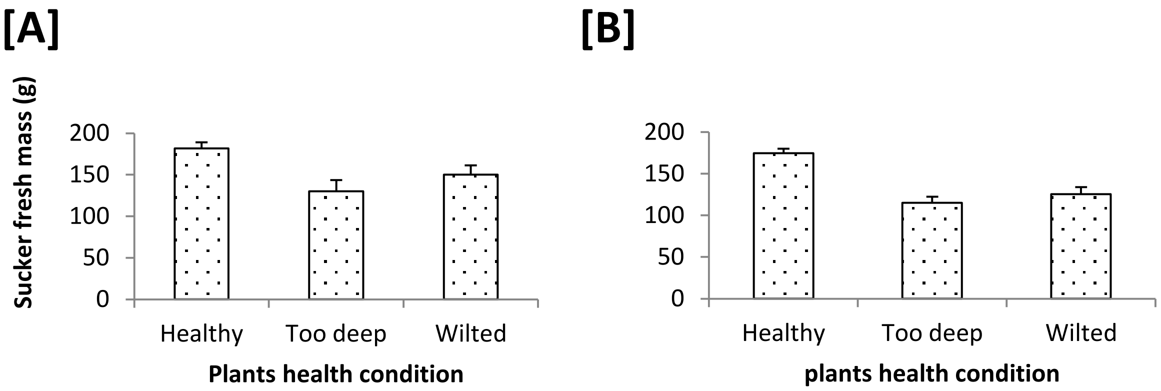


Figure 4.46. Effect of plant's health condition on sucker fresh mass (grams) in the March planting [A] and May planting [B] at 8 months after fruit harvest.

Interaction effect of plant's health condition and planting sucker size of mother plant

A significant interaction effect ($p < 0.05$) of plant health and planting sucker size of the mother plant was observed on sucker fresh mass in the March planting (Fig. 4.47). The general trend was that healthy plants established from sucker size 3, 4 and 5 produced heavier suckers than the plants planted too deep or from wilted plants (Fig. 4.47). There was no interaction effect between plant health condition and planting sucker size of the mother plant on sucker fresh mass in the May planting (data not shown).

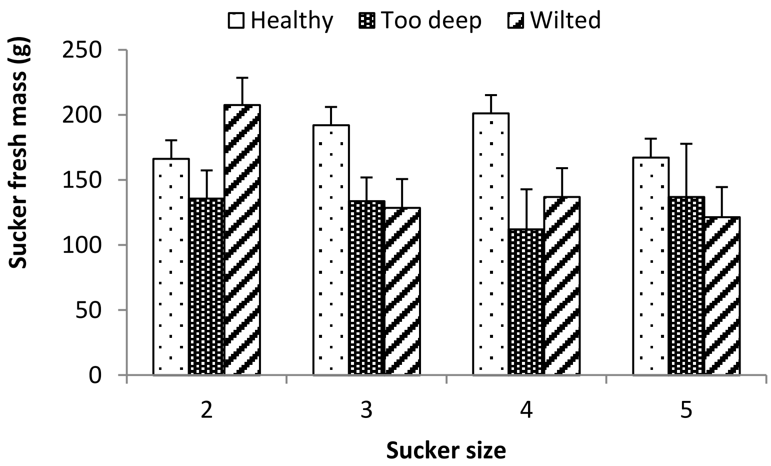


Figure 4.47. Interaction effect between sucker size and plant's health condition on sucker fresh mass, in the March planting at 8 months after fruit harvest.

4.4.7.3 Length (cm) of plantable suckers

Effect of the plant's health condition

Plant health condition had a significant effect ($p < 0.05$) on the length of the suckers produced by plants established from suckers that were planted 6 (May planting) and 8 (March planting) months after post-harvest $(NH_4)_2SO_4$ application (Fig. 4.48). Healthy plants produced significantly longer ($p < 0.05$) suckers in the March and May plantings than the plants planted too deep and those that were wilted (Fig. 4.48). The plants that were planted too deep had a significantly longer ($p < 0.05$) sucker length in the May planting than the wilted plants (Fig. 4.48 B). No significant difference was found between the plants planted too deep and the wilted plants in terms of sucker length in the March planting (Fig. 4.48 A).

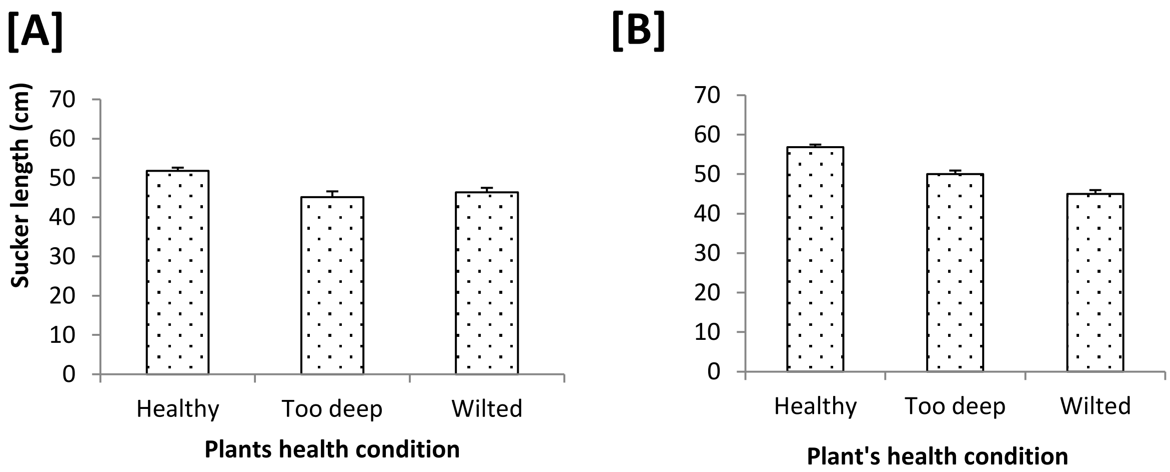


Figure 4.48. Effect of plant's health condition on sucker length in the March planting [A] and May planting [B] at 8 months after fruit harvest.

4.4.7.4. Effect of sucker size

There was a positive correlation between sucker size and sucker length of the healthy plants in the May planting (Fig. 4.49). The highest sucker length (55 cm) was observed in sucker size 2 while the lowest sucker length (46 cm) was observed in sucker size 5 (Fig. 4.49). There was no statistical significance on sucker length of the healthy plants in the March planting, but the results showed that plants established from larger sucker size produced longer suckers than the plants established from smaller sucker size (data not shown). Sucker size had no significant effect on sucker length of the plants that were wilted and planted too deep in the March and May planting (data not shown).

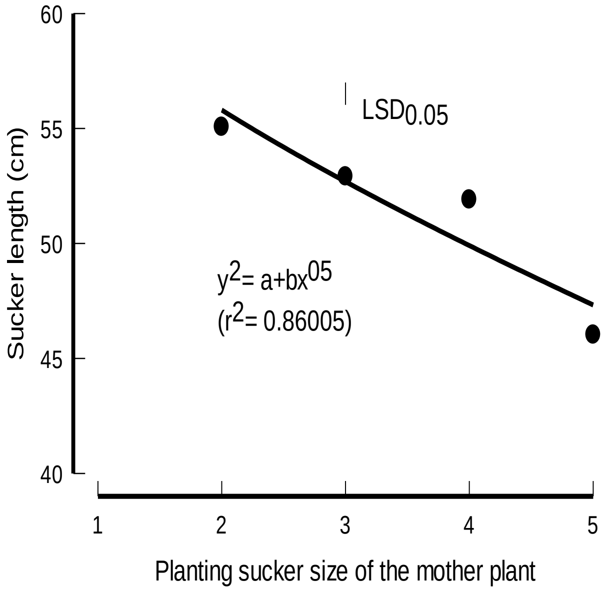


Figure 4.49. The relationship between planting sucker size of mother plant and the length (cm) of suckers produced by healthy plants in the May planting $(NH_4)_2SO_4$ at 8 months after fruit harvest. (Data points are means of 3 replicates).

Interaction effects of post-harvest $(NH_4)_2SO_4$ application and planting sucker size of mother plant

A significant ($p < 0.05$) interaction effect was observed between plant health condition and post-harvest $(NH_4)_2SO_4$ application in the May planting (Fig. 4.50). Healthy plants produced longer suckers in all the post-harvest $(NH_4)_2SO_4$ application treatments than the wilted plants and plants that were planted too deep (Fig. 4.50).

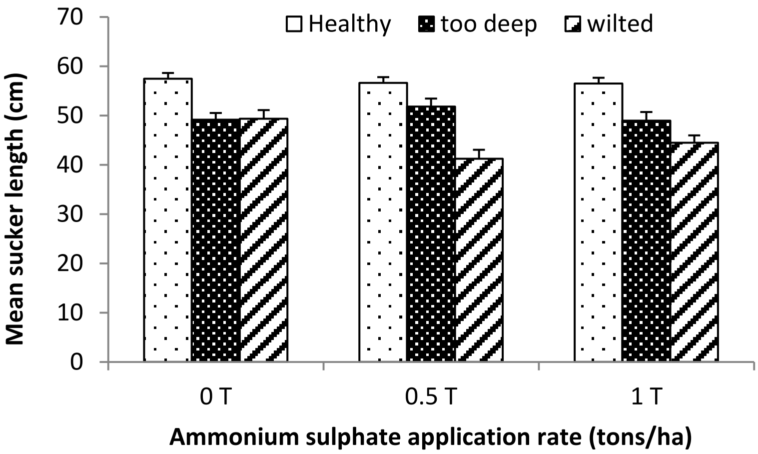


Figure 4.50. Interaction between plant's health condition and post-harvest $(NH_4)_2SO_4$ application, on sucker length in the May planting at 8 months after fruit harvest. (T = tons/ha).

4.5 DISCUSSION

4.5.1 Plant growth and development after planting

Post-harvest $(NH_4)_2SO_4$ application had a significant effect on plant fresh mass and stem diameter in all the plantings. The increase in plant fresh mass and stem diameter was positively correlated with the application rate of post-harvest $(NH_4)_2SO_4$. Amez et al. (2005), working with pineapple cv. Samba, reported that increasing the rate of nitrogen application during sucker growth, increased the subsequent growth of plants (mass and height) as well as the D-leaf length and fruit mass at harvest. Generally, higher levels of nitrogen increase vegetative growth (Mengel and Kirkby, 2001). In the current study the application of post-harvest $(NH_4)_2SO_4$ increased the fresh mass and length of the suckers while they were still on the mother plant and when these suckers were planted, their growth was improved. Dufault (1986) and Melton and Dufault (1991a), working on vegetable transplants, reported that supplying adequate nitrogen to seedlings before transplanting, improved shoot growth after planting. Widders (1989) reported that enhanced tissue N leads to improved nutrient uptake from the soil, which improves plant growth vigour.

Sucker size had a significant influence on plant growth potential, especially in the May and August planting. Generally, plant growth can be described as being similar to compound interest, i.e. the larger the initial plant, the higher the growth. On the contrary, in the present study, the data showed that larger suckers had less growth potential than the smaller suckers which in subsequent growth after planting increased more markedly in fresh mass and stem diameter than the larger suckers. Singh and Singh (1975) working on Giant Kew and Chadha et al., (1974) working on Cayenne pineapple, found that large suckers established slower than the smaller suckers after planting, although they had sufficient stored carbohydrates. Larger suckers were more sensitive to transplant shock than the smaller suckers; therefore, the percentage gain in fresh mass and stem diameter was higher on plants established from smaller suckers than plants established from larger suckers. The unexpected performance of the larger suckers compared with smaller suckers could be cultivar related, since Selamat (1995) observed in pineapple cv. Gandul that the growth rate of the plants was positively correlated with the size of the planting material.

The season of the year had a significant effect on the gain in plant fresh mass during the vegetative growth stage. The gain in plant fresh mass and stem diameter was also influenced by the length of the vegetative growth stage. Therefore, plant growth and development of the March, May and August plantings cannot be compared. Pineapple plant growth is most active in the first 3 to 5 months after planting (Py et al., 1987). Singh et al. (1998) found that pineapple vegetative growth is slower in the winter months than in the summer months. In phenology studies of the Queen pineapple in Hluhluwe, Rabie (personal communication) found that new leaves were formed at a rate of 1 per month in the winter and weekly in summer months. Due to the winter months following planting, the March and May plantings had their active growth from 6 to 9 months after planting with the March planting having 4 of its initial months of growth in winter and the May planting 2. Considering that this is a summer rainfall area, the dry conditions during the winter months also play an important role – see table 4.26 for the accumulative rain for the 6 months following planting in all 3 plantings. This explains why the March and May plantings had slow vegetative growth in the first 6 months after planting. The August planting was a summer planting, but unlike the March and May plantings, which were induced at 9 months, the August planting was induced at 7 months before plants could reach their maximum vegetative growth.

The results suggest that suckers obtained from plants treated with a higher application rate of post-harvest $(NH_4)_2SO_4$ have higher plant fresh mass and stem diameter, which is a characteristic desired by the pineapple producers.

4.5.2 Plant mortality symptoms

The percentage of wilted plants was high in all the plantings. In the March and August plantings, occurrence of wilted plants was the highest of all the mortality symptoms, while in the May planting it was the third highest percentage. In the current study, wilting could not be linked to mealybug infestation which is one of the two factors known to cause wilting. Drought is the other factor that can also cause wilting (Py et al., 1987). In the first 4 months little rain was received in the March and May plantings. This period of drought stretched over 6 months in the March planting. Plants in the August planting suffered from the opposite of drought namely too much moisture. The August planting was planted in an area which can be too wet when experiencing excessive rain, which was the case in the August planting. This, as well as the poor growth experienced in the planting, was then also the reason why the August planting was induced 2 months earlier than the norm.

After 6 months, plants that were planted too deep had a significantly higher percentage of dead and slow growing plants in the March and May plantings, than in the August planting. Although a high percentage of plants that were planted too deep was also found in the August planting, a high percentage of these plants recovered to healthy plants and it was likely due to the amount of rain falling after planting. The trials were conducted in an area with light sandy soil with clay content of 6 to 10%. After land preparation the soil becomes too soft making it difficult to measure the correct planting depth during the planting action. The result showed that plants planted too deep are only the result of human error during the planting activity. The correct planting method is important in improving fruit yield. A study comparing different planting materials and planting methods found that suckers planted shallow (about 5 cm deep) and upright produced higher yields than suckers planted more than 5 cm deep (Reynhardt and Dalldorf, 1968).

Only the March planting was significantly affected by the funnel rot symptom. It was discovered that there was negligence during post-plant ammonium sulphate application. The fertilizer was supposed to be applied by hand at the base of the plant, but for some reasons some was broadcasted over the plants, falling into the funnel and causing damage to the leaves. The results showed that larger plants were significantly affected because they are wide open having a higher chance of fertilizer falling into them. The labour was informed about the importance of fertilizer placement. The problem was considered solved because it did not happen again in the May and August plantings. Experiments conducted by Le Grice and Proudman (1968) confirm that funnel rot is a secondary effect caused by the ammonium sulphate when it falls into the heart of the pineapple plant. Destruction of the apical meristem in plants with strong apical dominance leads to rapid shoot formation (Kozlowski and Pallardy, 1997). The plants that were affected to an extent that the fertilizer burned the apical meristem, failed to produce fruit - they instead produced a lot of suckers. Those plants that were less affected, recovered and they produced fruit. Fruit quality depends on the extent of damage suffered by the plant (Le Grice and Proudman, 1968). Care should therefore, be emphasised in the application of $(NH_4)_2SO_4$ to pineapple to avoid the funnel rot problem.

The number of toppled over plants was high in the May and August plantings. The wind had an effect on toppling over, since the May planting was planted on a windy day and August is known to be the windiest month of the year. Toppling over of the plants can be managed by re-inserting plants into the soil if strong winds occur before the plants develop roots. Windbreaks can be planted around pineapple fields to minimize the effect of strong wind on plants.

Slow growth and dying back symptoms could not be explained. These symptoms are usually a result of a combination of several factors, such as disease, pests, environmental factors and poor nutrition. This makes it difficult to ascertain the cause unless the factor was monitored from the outset (Nadolmy, 1995).

Post-harvest ammonium sulphate application had a significant effect on plants planted too deep and plants affected by the funnel rot symptom in the March planting only. Plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $NH_4)_2SO_4$ produced more plants that survived the mortality symptoms and grew into healthy plants. These findings show that, using the planting material from plants treated with post-harvest $NH_4)_2SO_4$ wil be an advantage to the pineapple producers.

Sucker size had a significant effect in all 3 plantings but not on all the mortality symptoms. The effect of sucker size on mortality symptoms varied in all the plantings. Although Singh and Singh (1975) did not look at mortality symptoms, they found that larger suckers had a higher mortality percentage after planting than the smaller suckers. The current study found the same results with wilted plants, plants affected by the funnel rot and plants that toppled over. The opposite was found in plants planted too deep and plants that were dying back. In the March planting, sucker size had a significant effect on wilted plants and plants affected by the funnel rot. Plants established from larger sucker sizes were more affected than the plants established from smaller sucker sizes. In the May planting, wilted plants and plants that have toppled over that were established from larger sucker sizes were more affected than the plants established from smaller sucker sizes. In plants planted too deep and plants that were dying back, plants established from smaller suckers were more affected by the mortality symptoms than the plants established from the larger suckers. In the August planting, in the wilted plants, plants established from sucker size 5 were less affected than plants established from sucker size 2, 3 and 4. In the plants planted too deep, plants established from sucker size 2 were less affected than plants established from sucker size 3, 4 and 5. These results show that by understanding which of the mortality symptoms a particular size of the planting material is susceptible to, the pineapple producers can easily minimize the problem of plant mortality.

Six months after planting, the recovery and survival of the plants affected by mortality symptoms were influenced by the climatic conditions experienced. Most plants that recovered from the mortality symptoms and grew into healthy plants were in the August planting, while most of the plants that died due to plant mortality symptoms were in the March planting.

4.5.3 Mealybug and redmite infestation

The reason for low mealybug and red mite infestation was the effect of the pest control programme. As a standard practice, aldicarb was applied at 2 months after planting for nematode control, and it is also known to control mealybug and red mite population.

4.5.4 Percentage leaf nitrogen, phosphorus and potassium at red bud stage in the March, May and August planting

The percentage of nitrogen in the March planting was affected by sucker size. Plants established from smaller suckers had a higher concentration of nitrogen than plants established from larger suckers. Larger suckers have more nutrient reserves than the smaller suckers (Chadha et al., 1974). The levels of nutrients decrease as the plants get older (Py et al., 1987).With time smaller plants exhaust their nutrients faster than larger plants. In this case it is still an advantage to plant bigger suckers.

The percentage of phosphorus and potassium in the leaves was influenced by the application rate of post-harvest $(NH_4)_2SO_4$. The plants treated with 1 ton/ha post-harvest $(NH_4)_2SO_4$ application had a higher concentration of phosphorus and potassium than the plants treated with 0 ton/ha post-harvest $(NH_4)_2SO_4$ application. An increase in plant growth due to nitrogen improves the uptake of other elements such as phosphorus and potassium (Mengel and Kirkby, 2001). The significance of these findings is that, using the pineapple planting material with high accumulated nitrogen results into enhanced utilization of phosphorus and potassium. Research findings show that this results into plants producing higher yields of good quality fruits.

Sucker size and the time of planting had no influence on the percentage of phosphorus and potassium in leaves.

4.5.5 The occurrence of natural flowers and the percentage of flowering after flower induction

Natural flowering only occurred in the March and August plantings. Natural flowering occurs in plants big enough and old enough to flower, i.e. a plant must be of a certain age and size to flower naturally. Short days and low temperatures are the main factors inducing natural flowering (Rabie et al. 2010). It therefore occurs in the winter months and results from sudden drops in temperature associated with cold fronts (Lin et al., 2006). Shortening days and low temperature give rise to an increase in the natural production of ethylene in the stem apex and basal white leaf tissue of the pineapple plant which then stimulates flowering (Sanewski, 1998). The natural flowering in these trials can therefore be an effect of the time of planting which has an effect on the plant's vegetative growth vigour and the percentage flowering (Singh et al., 1998). The May planting was the least influenced as it was a winter planting. The August planting might have induced flowers while the suckers were still on the mother plant. Natural flowering can be triggered when a pineapple plant is subjected to drought or excess water stress as well (Minand Bartholomwe, 2002). Factors that promote vegetative growth in the pineapple tend to inhibit natural flower induction, and those which retard vegetative development stimulate flower induction (Miller-Watt, 1981). In the August planting, the impact of the stress might have been high on the plants in the 0 ton/ha fertilizer treatment, causing them to be more sensitive to natural flowering than the plants from the planting material that was treated with post-harvest $(NH_4)_2SO_4$. There are several factors causing the plant to be sensitive to natural flowering namely: cultivar, plant size, nutrient and pest pressure especially the nematodes (Lin et al., 2006). In the March and August planting, plants established from larger suckers were more likely to natural flowering than those from the smaller suckers. The same results were found in a study of natural flowering in Queen pineapple (Rabie et al., 2000). The rate of natural ethylene production in larger plants can produce enough ethylene to induce flowering, while in smaller plants the production rate of ethylene is insuficient for flower induction (Min and Bartholomew, 1993). Young pineapple plants have all the necessary factors required to induce flowering when treated with ethylene (Van de Poel et al., 2009).

Plants with mortality symptoms had a marked percentage of plants that failed to flower in response to flower induction. In the March planting, 19% of the plants were affected by mortality symptoms and 12% flowered after flower induction.In the May planting 26% of the plants had mortality symptoms and 21.3% flowered after FI. In the August planting 33.12% of the plants had mortality and 27.73% flowered after FI. The results showed that the percentage of plants that were affected by the mortality symptoms that failed to flower was lower than the percentage of affected plants that produced flowers. The percentage of plants that did not flower after FI was the highest in the March and lowest in the May planting.

It was only flowering of the wilted plants that was affected by post-harvest $(NH_4)_2SO_4$ application. In the May and August plantings, plants established from the smaller sucker sizes were more susceptible to flowering failure than the plants established from the larger plant sizes.

The percentage of plants that failed to flower in plants that had mortality symptoms was higher than the percentage of plants that failed to flower due to the unknown causes. The results of the study showed that plant size and the health condition of the plant have an effect on plant flowering. These results agree with the findings of Singh and Singh, (1975) on a study on Giant Kew pineapple. They found that flowering percentage increased with an increase in plant size as well as the rate of nitrogen application.

4.5.6 Fruit yield

The potential and average actual fruit yield was the highest in the May planting and the lowest in the August planting. The March and May plantings were induced 9 months after planting, while the August planting was induced 7 months after planting. The August planting was induced earlier than expected because after receiving 500 mm of rain in the first 6 months after planting, the field proved to have poor drainage and the plants were starting to show signs typical of oxygen depleted soils. The results of the study showed that it is important to induce plants at the correct vegetative stage to obtain maximum yield. A study by Latha et al., (1997) on pineapple cv. Mauritius found that inducing flowers 8 months after planting achieved greater yields than when inducing at 6 and 7 months after planting, and he further explained that the time of planting also played a role. In this study the poor conditions of the planting area played a role in reduced yield in the August planting. Chapter 3 results show that the August planting was planted with suckers that had declining growth, therefore the poor quality of the planting material could be one of the reasons the yield was lower than the March and May planting. Fruit yield is dependent on the quality of the planting material (Chadha et al., 1974).

Fruit yield in the August planting was significantly lower than in the March and May plantings, that was why the tons of fruit yield lost were much lower than the percentage of plants when compared to the March and May plantings.

Fruit yield was dependent on plant size and the amount of fertilizer applied. Plants established from larger suckers produced higher yield than plants established from smaller suckers. Plants treated with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ produced higher yield than plants treated with 0 ton/ha post-harvest $(NH_4)_2SO_4$ application. These results agree with the finding of Singh and Singh, (1975) who found that larger size suckers and higher doses of nitrogen are a prerequisite for the production of higher fruit yield. A study done on the quality and size of the planting material on Kew pineapples, found that larger sucker sizes had better development and produced larger yield and larger fruits than the smaller suckers (Chadha et al., 1974). Plants established from smaller suckers had higher yield loss than plants established from larger suckers.

The results show that treating plants with 0.5 ton/ha and 1 ton/ha post-harvest $(NH_4)_2SO_4$ can increase the profits of the farmers and cover the cost of the fertilizer used.

4.5.7 External and internal fruit quality at harvest

Post-harvest $(NH_4)_2SO_4$ application had a significant effect on fruit quality in all the plantings. It had an effect on the winter speckle occurrence, inter-fruitlet cracking and TSS. Nitrogen determines plant growth and fruit mass as well as other factors associated with fruit quality. Higher rates of nitrogen result into lower brix (Py et al., 1987).

Sucker size had a significant effect in all the plantings and it influenced fruit size, inter-fruitlet cracking, winter speckle occurrence and TSS. Fruitlet spirals and fruit length were lower in fruit from smaller suckers than in fruit from larger suckers. The number of inter-fruitlet cracks, crown fresh mass, winter speckle occurrence, and TSS were higher in fruit from smaller suckers than in fruit from larger suckers. Fruit from smaller planting material reach maturity earlier than fruit from larger planting material (Chadha et al., 1974). Since all the treatments were harvested at the same time, the fruit from smaller plant sizes matured earlier and had more time to increase

TSS before the maturity of fruit from larger plant sizes. All the treatments were affected by inter-fruitlet cracking. In cases where there was high incidence of inter-fruitlet cracking, as happened in the May planting, smaller fruit, which were produced by plants established from smaller suckers, were more affected. Rabie and Tustin (2006) states that major factors causing winter speckle have not been found yet. There is an indication that climatic conditions could be a contributing factor. The results of the study support that theory in the sense that fruit from smaller plant sizes were more exposed to factors causing winter speckle than the fruit from the larger plant sizes, hence the higher winter speckle occurrence. Larger plants with longer leaves can protect the fruit from the environmental elements that might deteriorate the external quality of the fruit (Py et al., 1987). Selamat (1995) working on Pineapple cv. Gandul found that the size of the planting material affected only the external quality parameters of the fruit

The number of fruitlets produced determines the length of the flowering period as well as the mass of the fruit. Smaller fruit sizes have short flowering period and the larger fruit sizes have a longer flowering period (Py et al., 1987). The results of this study showed that fruit size was influenced by sucker size. There was a positive correlation between the fruit length and the number of fruitlets per spirals. In the May and August planting, crown fresh mass was influenced by the sucker size. Plants established from larger suckers produced larger fruits with smaller crowns, while plants established from smaller suckers produced smaller fruits with larger crowns. In the March planting there was no relationship between sucker size and crown fresh mass, therefore it could be influenced by the season of growth, since the May and August planting were harvested at the same time.

4.5.8 Post-harvest internal fruit quality

Black spot, nectary duct and internal browning infestation can start to occur before fruit harvest but only an insignificant number of fruit are affected at that stage. The number of affected fruit and infestation levels can be made severe by the length and conditions of storage after fruit harvest (CSFRI 1991; Nanayakkara. 2005). A ripe pineapple fruit can be stored at a temperature of 4.5 – 7 °C, at 85% – 90% relative humidity for the maximum period of 14 to 21 days, but when kept at room temperature it can be stored for 7 to 14 days (CSFRI 1991). The results of the study agree with the literature. There was less nectary duct, black spot and internal browning at 7 days than at 14 days after fruit harvest. Reducing the time of fruit storage can minimize some of the post-harvest fruit disorders (Nanayakkara. 2005).

4.5.9 Post-harvest sucker yield evaluation

Healthy plants produced more plantable suckers than the plants that were planted too deep and those that were wilted.

The performance of the plants that were planted too deep in this trial produced lower sucker yield than the healthy plants, which was similar to the findings of Reynhardt and Dalldorf (1968) who found that queen pineapples that were planted too deep produced poor fruit and sucker yield. There was a positive correlation between plant size and the number of plantable suckers produced. Plants established from larger sucker sizes produced more plantable suckers than the plants established from the smaller sucker sizes. These findings correspond to those of Heenkenda (1993) who found that larger plants produced a higher sucker yield than the smaller plants. Bigger plants have sufficient stored carbohydrates to support the suckers to grow into quality planting material (Chadha et al., 1974).

Sucker fresh mass and length were influenced by the health condition of the plant and plant size. Chadha et al., (1974) and Selamat, (1995), found that the size and quality or health condition of the pineapple plant have an effect on plant growth rate and performance in terms of fruit yield and sucker production. The interaction effect between sucker size and plant health showed that larger plants of poor quality stand a better chance of producing heavier suckers than the poor quality plants of smaller sizes. Post-harvest $(NH_4)_2SO_4$ application had no significant effect ($p < 0.05$) on sucker yield as well as sucker fresh mass and length, on the plants planted from the planting material treated with post-harvest $(NH_4)_2SO_4$. .

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusions

Several hypotheses were tested on how to improve the quality of the planting material in order to achieve higher fruit and sucker yield. These hypotheses were tested on the effect of post-harvest $(NH_4)_2SO_4$ application on sucker development and growth period (months) required to grow suckers on the mother plant after fruit harvest. In the subsequent plantings, the hypotheses were tested on the effect of post-harvest $(NH_4)_2SO_4$ application, sucker size and the time of planting on plant growth - i.e. the gain in fresh mass and stem diameter, plant mortality symptoms, *Mealybug* and *red mite* infestation, the percentage of N, P and K in leaves, flowering percentage, fruit yield, fruit quality and sucker yield.

Contrary to the first hypothesis the results of the study showed that fertilizer on its own had no significant effect on sucker growth and development while still on the mother plant . Sucker growth in terms of fresh mass and length on the mother plant, was influenced by the interactions of the duration of the sucker growth period with post-harvest $(NH_4)_2SO_4$ application. These results supported the first hypothesis.

The duration of sucker growth period is positively correlated to the number of suckers produced, while post-harvest $(NH_4)_2SO_4$ application had an effect on sucker size. Eight months is the optimum length of time required to produce quality planting material, after post-harvest $(NH_4)_2SO_4$. These results support the second hypothesis.

In support of the third hypothesis, the results proved in the subsequent plantings that when suckers are not sorted correctly or strict measures are not taken to eliminate poor planting material, problems of poor plant growth and development as well as plant mortality could arise during the growth cycle and have a negative influence on fruit yield as well as sucker yield.

There was a positive correlation between sucker size and post-harvest $(NH_4)_2SO_4$ application on the percentage gain in plant fresh mass and stem diameter . The time of planting and the length of the vegetative growth period had an effect on gain in plant fresh mass and stem diameter.

The results of the study proved that the health condition of the plant affects fruit yield. The results of the study showed that planting too deep, toppling over and funnel rot could be completely eliminated by proper planting and crop management methods. The study could not identify the causes of wilted plants, slow growing plants and plants that were dying back, but with strict plant grading methods these mortality symptoms could be minimised. Eliminating or minimising the mortality symptoms improved the quality and health of the plant therefore increasing the fruit and sucker yield.

The infestations by mealybug and red mite were low and were not affected by post-harvest $(NH_4)_2SO_4$ application, sucker size and the time of planting. This study showed that, having a proper pest management program is a necessity in minimizing the infestation of pests.

Post-harvest $(NH_4)_2SO_4$ application improved the phosphorus and potassium percentage in the leaves in the May and August planting.

Plants established from smaller suckers had a significantly higher percentage of plants not flowering after flower induction than the plants established from bigger suckers. Only the March and August plantings were affected by natural flowering. The total percentage of plants that did not flower due to plant mortality symptoms was higher than the total percentage of plants that did not flower due to the unknown causes.

Plants established from bigger suckers produced higher fruit yield than plants established from smaller suckers. Fruit yield loss due to mortality symptoms was higher than that due to the unknown causes. In this study the total percentage of plants that did not produce fruit was high in the March planting 15%, followed by the August planting 7.56% and low in the May planting 6.03%.

The results on external and internal fruit quality showed that post-harvest $(NH_4)_2SO_4$ application had an effect on fruit length, inter fruitlet cracking, winter speckle occurrence and brix. Sucker size had an effect on the number of fruitlet spirals, fruit length, crown fresh mass, inter fruitlet cracking, winter speckle occurrence and TSS. External and internal fruit quality was not affected by the time of planting.

There was a positive correlation between the number of storage days after fruit harvest and the occurrence of black spot and nectary duct infection as well as for internal browning.. Post-harvest $(NH_4)_2SO_4$ application, sucker size and the time of planting had no significant effect on the results.

There is a positive correlation between the health condition of the plant and sucker yield. Post-harvest $(NH_4)_2SO_4$ application had no significant effect on sucker yield.

The fourth hypothesis was supported by the results, depending on the stage of growth of the plant and the parameter that was measured.

5.2 Recommendations and suggestion for future research

Based on the results of the study, the following recommendations can be made.

1. Post-harvest $(NH_4)_2SO_4$ should be applied to help improve the quality of the planting material. The optimum time required to leave the suckers to grow on the mother plants after fruit harvest is 8 months. Grading the suckers by length is more effective than grading by fresh mass as it produces more planting material. Correct placement of post-plant $(NH_4)_2SO_4$ application is important to avoid fertilizer burn which leads to funnel rot. Plants should be planted at the correct depth to avoid planting too deep or toppling over.

2. Further research is still required to determine the length of time the suckers should be left to grow on the mother plant to produce quality planting material in both summer and winter months. More research is needed to improve the nutrition of the mother plant and field sanitation practices after fruit harvest as it affects the quality of the planting material.

3. Pineapple farm labourers need to be trained to understand the importance of proper plant grading, planting and correct fertilizer placement, to minimise fruit yield loss. The results of the study identified some of the mortality symptoms as a direct result of poor planting and crop management practices.

4. The total percentage of plants that did not flower due to plant mortality symptoms was higher than the total percentage of plants that did not flower due to the unknown causes. Based on the findings of this study, a study needs to be conducted to identify the unknown causes that lead to healthy growing plants not producing flowers after flower induction.

5. Since the results of the current study could not identify the factors causing slow growth and dying back symptoms, an investigative study needs to be conducted to find the factors causing these symptoms as well as how they can be minimized

6. Fruit quality from plants affected by the mortality symptoms should also be evaluated individually when doing trials in future.

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APPENDICES

Table 1 A. Actual data used to calculate the effect of time on the percentage increase in sucker fresh mass and length in KH10.

Block KH10			
Time interval after post-harvest $(NH_4)_2SO_4$ application	2 months	8 months	Increase in sucker fresh mass (%)
2 - 8 months	19.692	62.013	227
	8 months	10 months	
8 - 10 months	62.013	52.314	-14
$LSD_{0.05}$			65.1
Time interval after post-harvest $(NH_4)_2SO_4$ application	2 months	8 months	% sucker length increase
2 - 8 months	12.766	30.25	144.1
	8 months	10 months	
8 - 10 months	30.25	29.06	-3.5
$LSD_{0.05}$			27.6

Table 1 B. Actual data used to calculate the effect of time on the percentage increase in sucker fresh mass and length in KH15.

Block KH15			
Time interval after post-harvest $(NH_4)_2SO_4$ application	4 months	6 months	Increase in sucker fresh mass (%)
4 - 6 months	45.56	72.29	60.9
	6 months	8 months	
6 - 18 months	72.29	97.66	41.4
$LSD_{0.05}$			31.8
Time interval after post-harvest $(NH_4)_2SO_4$ application	4 months	6 months	% sucker length increase
4 - 6 months	22.38	40.20	80.9
	6 months	8 months	
6 - 18 months	40.20	46.34	17.8
$LSD_{0.05}$			22.5

Table 2 A. Actual data used to calculate the effect of time on the percentage increase in mother plant stem length and diameter in KH10.

Block KH10			
Time interval after post-harvest $(NH_4)_2SO_4$ application	2 months	8 months	Increase in sucker fresh mass (%)
2 - 8 months	9.74	12.4	12.4
	8 months	10 months	
8 - 10 months	12.4	12	-2.5
$LSD_{0.05}$			8.8
Time interval after post-harvest $(NH_4)_2SO_4$ application	2 months	8 months	% sucker length increase
2 - 8 months	4.55	5.10	30.7
	8 months	10 months	
8 - 10 months	5.10	4.95	-0.4
$LSD_{0.05}$			29

Table 2 B. Actual data used to calculate the effect of time on the percentage increase in mother plant stem length and diameter in KH15.

Block KH15			
Time interval after post-harvest $(NH_4)_2SO_4$ application	4 months	6 months	Increase in sucker fresh mass (%)
4 - 6 months	6.24	7.54	21.8
	6 months	8 months	
6 - 18 months	7.54	7.38	-1.5
$LSD_{0.05}$			14.4
Time interval after post-harvest $(NH_4)_2SO_4$ application	4 months	6 months	% sucker length increase
4 - 6 months	4	4.61	15.5
	6 months	8 months	
6 - 18 months	4.61	4.51	-2.1
$LSD_{0.05}$			5.7