

**GROWTH AND YIELD RESPONSES OF THREE GENOTYPES OF
PASSION FRUIT (*Passiflora* var. *flavicarpa* and var. *edulis*) TO THREE
LEVELS OF POTASSIUM FERTILIZER TREATMENT UNDER TWO
ENVIRONMENTS**

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**UNIVERSITY OF NIGERIA, NSUKKA
DEPARTMENT OF CROP SCIENCE**

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TITLE PAGE

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POTASSIUM FERTILIZER TREATMENT UNDER TWO ENVIRONMENTS**

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**A DISSERTATION SUBMITTED TO THE DEPARTMENT OF CROP SCIENCE,
UNIVERSITY OF NIGERIA, NSUKKA IN PARTIAL FULFILMENT OF THE
REQUIREMENT FOR THE AWARD OF MASTER OF SCIENCE (M.Sc) IN CROP
SCIENCE (TROPICAL FRUITS AND PLANTATION CROPS)**

SUPERVISOR: PROF. K.P. BAIYERI

SEPTEMBER, 2018

CERTIFICATION

This is to certify that **OKPALAEKE IFEOMA VIRGINIA**, a postgraduate student of the Department of Crop Science, University of Nigeria, Nsukka with registration number **PG/M.Sc/15/78855**, has satisfactorily completed the requirements for the research work for the award of the degree of Master of Science (M.Sc.) in Crop Science (Tropical Fruits and Plantation Crops). The work embodied in this dissertation is original and has not been submitted in part or full for any other diploma or degree in this or any other University.

Prof. K.P. BAIYERI
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Date

Prof. M.U. Ndubuaku (Mrs)
(Head of Department)

Date

DEDICATION

To God Almighty and Blessed Mother of Perpetual Help.

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TABLE OF CONTENTS

Title Page	i
Certification	ii
Dedication	iii
Acknowledgement	iv
Table of Contents	v
List of Tables	vi
Abstract	viii
INTRODUCTION	1
LITERATURE REVIEW	
Origin of Passion fruit	4
Description	4
Distribution of passion fruit	5
Adaptation	6
Varieties of passion fruit with their characteristics	7
Climatic requirements of passion fruit	8
Wind protection	10
Soil requirement of passion fruit	10
Propagation	11
Early growth of passion fruit	12
Cultural requirement in passion fruit farming	13
Prunning	14
Fertilization	15
Transplanting	15
Trellising system	15

High tunnel	16
Mineral nutrition and nutrient uptake in passion fruit	16
Nutritional value of passion fruit	18
Health benefit of passion fruit	18
MATERIALS AND METHODS	21
Experimental site	21
Soil sample and seed collection	21
Experiment 1	22
Experiment 2	22
Biochemical analysis of passion fruit	23
Statistical analysis	23
RESULTS	24
DISCUSSION	61
CONCLUSION	70
REFERENCES	71
APPENDIX	76

LIST OF TABLES

Table 1: Main effect of environment on growth parameters of passion fruit at different months after treatment application	25
Table 2 Main effect of genotype on growth parameters of passion fruit at different months after treatment application	27
Table 3: Main effect of potassium Fertilizer on growth parameters of passion fruit at different months after treatment application	29
Table 4: Main effect of environment and fertilizer interaction on the growth parameters of passion fruit at different months after treatment application	30
Table 5: Main effect of environment and genotype interaction on the growth parameters of passion fruit at different months after treatment application	33
Table 6: Main effect of genotype and fertilizer interaction on the growth parameters of passion fruit at different months after treatment application	36
Table 7: Main effect of genotype, environment and potassium fertilizer on the dry matter of three genotypes of passion fruit	39
Table 8: Effect of genotype x potassium fertilizer interactions on the dry matter of the two genotypes of passion fruit	41
Table 9; Effect of environment x k-levels interactions on the dry matter of the two genotypes of passion fruit	41
Table 10: Effect of genotype x environment interactions on the dry matter of the two genotypes of passion fruit	42
Table 11: Main effects of environment, genotype and k-levels on the leaf and vine of the three passion fruit	44
Table 12: Effects of Environment and genotype interaction on the leaf and vine of the three passion fruit	46
Table 13: Effects of Environment and potassium fertilizer interaction on the leaf and vine of the three passion fruit	48
Table 14: Effects of environment x genotype x potassium fertilizer on the leaf and vine of the three passion fruit	48
Table 15: Fruit matrix traits as influenced by genotype, K- levels	50
Table 16: Effects of genotype, k-levels and their combination on fruit yield and yield components of passion fruit	51

Table 17: Effects of genotype, potassium level, and their combination on percentage weight loss of two genotypes of passion fruit.	53
Table 18: Main effect of genotype and K-levels on the mineral content of the passion fruit	55
Table 19: Effect of genotype and K-levels interaction on the mineral content of the passion fruit	55
Table 20: Main effect of genotype and K-levels on the proximate content of the passion fruit	57
Table 21: Effect of genotype and K-levels interaction on the proximate content of the passion fruit	57
Table 22: Main effect of genotype and K-levels on the phyto-chemical content of the passion fruit	59
Table 23: Effect of genotype and K-levels interaction on the phyto-chemical content of the passion fruit	59
Table 24: Main effect of genotype and K-levels on the phyto-chemical content of the passion fruit	61
Table 25: Effect of genotype and K-levels interactions on the phyto-chemical content of the passion fruit	61

ABSTRACT

Two environments (high tunnel and open field) and three levels of potassium fertilizer (0kg/ha, 100kg/ha and 200kg/ha) were evaluated for their effects on early growth and yield of three genotypes of passion fruits - conventional, purple and hybrid KPF-4. Seedlings grown under the two environments showed significant ($p<0.05$) differences for the morphological growth parameters at varying months after treatment application. Highest numbers of unifoliate leaves 42.2, were observed in the open field than in the high tunnel 12.7. However, Longest vine 300.9cm was observed in plants inside the high tunnel compared to the open field that gave 105.6cm. Number of bifoliate and trifoliate leaves were not significantly different in the two environments but more were produced by plants inside the tunnel. Furthermore, number of unifoliate, bifoliate and trifoliate leaves, number of branches and vine length varied among the three genotypes; KPF-4 had the highest values than the other genotypes. Different levels of potassium fertilizer (muriate of potash) applied did not show significant difference although plants that received 200kg k_2O /ha of potassium fertilizer produced more bifoliate and trifoliate leaves while vine length, number of unifoliate leaves and branches were higher on those that received 100kg k_2O /ha than those with no fertilizer. Comparison of fresh weight of vine, leaf and total dry matter yield indicated that KPF-4 seedlings grown under the tunnel gave the best results. The combined effects of potassium and genotype revealed that conventional genotype with 100kg k_2O /ha produced more juice volume and weight while the hybrid with 200kg k_2O /ha had longer, wider and thicker fruits than those with no fertilizer. Percentage weight loss varied significantly ($p<0.05$) among the three rates of potassium fertilizer. Increase in weight loss was observed in plants with no fertilizer than those with fertilizer. Evidences from the study revealed that high tunnel and different rates of potassium fertilizer enhanced growth and yield quality of passion fruits. The hybrid KPF-4 grown with 100kg k_2O /ha gave the best results than other genotypes.

INTRODUCTION

Passion fruit is one of the extremely important and versatile types of tropical fruits grown all over the world whose demand is growing both in export and domestic markets. It is a vine species of passion flower that is native to Southern Brazil through Paraguay to Northern Argentina (Manica, 1981). This exotic fruit belongs to the family of Passifloraceae of the genus *Passiflora*. Passion fruit is a shallow-rooted, woody perennial plant that climbs by means of tendrils to almost any support (Morton, 1987). This crop is propagated either by seed or through cuttings and can grow up to a height of about 5-7m per year once established and must have strong support. The plant is short-lived for about 5-7 years. There are several varieties of passion fruits but the most commonly cultivated edible types are the yellow passion fruits (*Passiflora. edulis Sims f. flavicarpa Deg.*) and the purple passion fruits (*Passiflora. edulis Sims f. edulis*).

The purple variety is smaller, less acidic, varies in taste and juiciness, has intense aromatic scent and does better at higher altitude whereas the yellow type is bigger, has similar taste, less aromatic, more acidic, has more vigorous vine, tend to yield higher and is more resistant to diseases (Maciel *et al.*, 1997) and also grows well in hot low-lying areas (Bradtke, 2010). Both varieties are green before ripening and are grown for commercial and domestic purposes.

Commercial quantities of passion fruit are mostly produced in greenhouses where rainfall is low to moderate and dry season is long (Paull and Duarte, 2012). In recent times, passion fruits are not only cultivated in an open field but also in a growing system similar to green house popularly known as high tunnel used in horticultural industries to protect microclimatic variables as well as increasing yields than field crops (Jiang *et al.*, 2003).

Among fruits, it has been considered an attractive farming choice since it provides a fast economic return. The fruit can be eaten fresh or consumed as fruit juice and other

formulations containing the fruit. Fresh passion fruit juice is a good source of protein (5.2 g/cup of fruit juice), rich in mineral salts and vitamins such as Vitamin A (3002IU) and C (70.8mg), which are important for the healthy development of children, pregnant women and the elderly (Khalid *et al.* 2004). Nearly, half of the fresh fruit yield can be converted to juice that is high in antioxidants. With high export value, it can serve as potential source of foreign earnings. In addition to high vitamin C content, passion fruit also contains the B vitamin niacin that helps in the creation of certain enzymes, as well as in the formation of important chemical messengers in the brain. However, these exotic fruits also contain a lot of potassium, iron and phosphorus. The seeds are used to manufacture soap, paint, cooking oils and rich in insoluble dietary fibre(64g/100g) that serve as an effective functional ingredient to promote intestinal amylase activity and reduction of caecal pH and caecal ammonia content (Chau and Huang, 2004; Chau *et al.*, 2005). Passion fruit leaves contain oil that can be used for domestic, industrial and medicinal purposes and reported to have the ability to cure diseases such as urinary tract infection, chronic inflammations, asthma and hypertension (Decuypere, 2000). Passion fruit, being a highly valued crop across the world, is rarely cultivated in warm high rainfall environments; In Nigeria, it is still an unexplored kind of fruit farming in spite of its importance. Its production is low and mostly restricted to the moist savannah zone and its average yield is nearly ten-fold lower than production obtained in other parts of the world. Apart from the fact that passion fruits, just like any other fruit, has its good and bad seasons, lack of appropriate fertilizers treatment could possibly be one of the limiting factors because fertilization is one of the agronomic practices in fruit farming that influences productivity, quality and shelf life of fruits.

According to Baiyeri *et al.* (2011) fertilizer treatments influenced seed quality, seedling emergence and growth quality of passion fruits. The sensitivity of passion fruit plant to potassium fertilizer under low to moderate atmospheric conditions is well known but its

response under conditions of high rainfall, relative humidity and temperature is less reported. The questions now are can three genotypes of passion fruit seedlings thrive in a high tunnel under the warm high rainfall conditions of Nsukka and environments. Also, what would be the levels of potassium fertilizer requirement, if they are to be grown under high tunnel conditions and in the field?

Therefore, the general objective of this study was to evaluate the growth and development pattern of three genotypes of passion fruit seedlings to potassium fertilizers under the warm, humid, high rainfall environmental condition in Nsukka. However, the specific objectives of this study were to:

1. Determine the effect of high tunnel on the growth pattern of three genotypes of passion fruit;
2. Evaluate the effect of three levels of potassium fertilizer on the growth and dry matter accumulation of the three genotypes of passion fruit; and
3. Investigate the effect of three rates of potassium on post harvest and nutritional quality of the three genotypes of passion fruit.

LITERATURE REVIEW

ORIGIN OF PASSION FRUIT

Passion fruit is one of the oldest fruits grown since centuries; it is a vine spice of passion flower that is native to Southern Brazil through Paraguay to Northern Argentina (Manica, 1997). This exotic fruit belongs to the family of Passion Floraceae of the genus *Passiflora*. Its scientific name is *Passiflora edulis*. The name was given by Spanish Catholic Missionaries in Brazil “as flower of the five wounds” after its distinctive purple flower to illustrate the passion of Christ (the five petals and five sepals with the ten apostles, the corona with the crown of thorns, the five stamens with the five wounds, and three pistils that represent the three nails used in the crucifixion) as had already been pointed out by Nicolás Monardes, in 1569 (Harms, 1925; Kugler and King, 2004; Pryce *et al.*, 2014). Report by (Vieth, 2017) showed that the family Passifloraceae contains about 580 species of which 400 are in the genus *Passiflora*; of these all but about 40 are indigenous to tropical and subtropical America. They are commonly found as understory plants in rain forests. The unusual flowers are the outstanding characteristic of passifloras and many are grown only for their flowers. There are several types of passion fruits which can vary in size and colour but the most commonly cultivated edible types are the yellow passion fruits (*Passiflora flavicarpa*) and the purple passion fruits (*Passiflora edulis*). The purple passion fruits originated from Southern Brazil while the yellow passion fruit is of unknown origin (Nakasone and Paull 1999). It is believed that it is a native of the Amazon region of Brazil or a hybrid between *P.edulis* and *P. ligulans* but Strohalm *et al.* (2007) reported that yellow passion fruit is a native of Ecuador and Brazil.

DESCRIPTION

Passion fruit is oval or round in shape with a structure somewhat like a watermelon. The vine is a shallow-rooted, woody perennial plant that climbs by means of tendrils to almost any

support (Morton, 1987). It can grow up to a height of about 5-7m per year once established and most have strong support. The plant is short-lived about 5-7 years (CRFG, 1996). The leaves are alternate, evergreen, and deeply 3-lobed and finely toothed when matured. They are (7.5-20cm) long, deep green and glossy above, paler and dull beneath, and like the young stem and tendrils, tinged with red or purple, especially in the yellow form. It bears a single fragrant flower of about 5-7.5cm wide in each node on the new growth. The bloom is held by three large green leaf-like bracts and consists of five greenish white sepal, 5 white petals, a fringed corolla of strength, white tipped rays, rich purple at the base (Morton, 1987). The flowers are bisexual, colorful, possessing a complex corolla, and a superior ovary on gynophores. Also the flower bears 5 stamens with large anthers, the ovary and triple branched style forming a prominent central structure. The flower of the yellow variety is more showy with more intense colour but self-sterile hence the most efficient pollinator is Carpenter Bees. Wind is an effective agent of pollination because of the heaviness and stickiness of the pollen. The flower can also be hand pollinated. The fruit is 4-7.5cm wide; usually ripen from flowering in 80 days. It has a tough rind, smooth, waxy and the outside colour ranges from dark-purple with faint white specks to light-yellow or pumpkin colour. Within a cavity is an aromatic mass of double-walled membranous sac filled with orange-coloured pulpy juice and about 250 small, hard, dark-brown or black, pitted seed.

DISTRIBUTION OF PASSION FRUIT

The purple passion fruit partially naturalized in coastal areas of Queensland in Australia before 1960. Its cultivation especially on abandoned banana plantations attained great importance; it was discovered to be disease free and can easily be managed. At about 1943, a widespread invasion of fusarium wilt killed the vines and this forced the undertaking to carry out research to find out the fungus resistant substitutes. Later it was discovered that the neglected yellow passion fruit is both wilt and nematode resistant and does not break off from

roots as against the purple passion fruit. The yellow passion fruit was adopted as a root stock and propagated by grafting was soon made available to planters in Queensland and Northern New South Wales. Also in the last few decades Australians have begun to adopt hybrids of the purple and yellow which have strong ability to withstand the serious virus disease called woodiness. The seeds of purple passion fruit brought from Australia were first planted in Hawaii around 1880 and the vines came to be popular from Australia in home gardens. It quickly became naturalized in the lower forest and by 1930, could be found wild on all islands of the Hawaii chain (CRFG, 1996).

In India cultivation of yellow passion fruit was quickly approved as it has a more pronounced flavour than the purple variety and produces within a year of planting heavier and more regular crops while commercial production of purple passion fruit began in Kenya in 1933 and was expanded in 1960 when the crop was also introduced into Uganda for production (Morton, 1987; Joy, 2010). In both countries, the large plantations were devastated several times by easily-spread diseases and pests. In 1947, about 2,000 tons of purple passion fruit were produced in South Africa which was doubled in 1950 (Morton, 1987). The yellow passion fruit, whose origin has been linked to Southern Brazil was introduced from Europe and Asia into Nigeria in the 1980s and is now being grown in some parts of Northern Nigeria (Alegbejo, 2004). African countries that are in the forefront of passion fruit cultivation, processing and utilization include Kenya, Uganda, South Africa, Ivory Coast and Zimbabwe (Gachanja and Gurnah, 1995; Morton, 1987).

ADAPTATION

Passion fruit is widely grown in tropical and semi tropical regions of the world. Certain cultivars are resilient against light frosts and thus can survive perennially even in more temperate climates such as that of Great Britain. The purple passion fruit is subtropical and prefers a frost-free climate. However, there are cultivars that can take temperatures into the

upper -7°C without serious damage. The vines may lose some of their leaves in cool winters; their roots often re-sprout even if the top is killed. The plant does not grow well in intense summer heat. The yellow passion fruit is tropical or near tropical and is much more intolerant of frost. Both forms need protection from the wind. Passion fruit vines make good container specimens but require maintenance. Generally, passion fruit vines are trained to strongly supported trellis at least 21.3m high. However, it should be noted that the yellow passion fruit is more productive and less subjective to pests and diseases if allowed to climb a tall tree.

VARIETIES OF PASSION FRUIT WITH THEIR CHARACTERISTICS

Several distinct varieties of passion fruit with clearly exterior appearance exist. Among the fifty-five (55) species that bear edible fruits, only ten are of commercial value (Martin and Nakasone, 1970). *Passiflora edulis* (2n=18) is the most widely cultivated species (De melo and Guerra, 2003).

However, the yellow and purple fruits are the most famous varieties cultivated in Nigeria. The major varieties grown worldwide with their feature include:

i. Yellow/Golden passion fruit (*Passiflora edulis f.flavicarpa Degener*)

This variety is round to oval in shape and can grow up to the size of a grape fruit (8-10cm long, 4-10cm diameter). It has a smooth glassy light and airy thick (3-4mm) rind of yellow to light orange pulp having highly aromatic and acidic juice. The fruit is bigger in size than the purple variety, each weighing about 60-90grams turns golden colour when well ripe and contains prunasin and other cyanogenic glucoside in the peel and juice. It has good degree of tolerance for pests and diseases.

ii. Purple passion fruit (*Passiflora edulis sims F. Edulis*)

The fruit is round to oval in shape measuring 5-8cm long and 4-8cm in diameter. It weighs about 35-50grams and turns to deep purple colour when ripe with tough, woody smooth rind.

The pulp is less acidic, richer in aroma and flavour and has a high proportion of orange yellow coloured juice.

iii. Giant Granadilla (*Passiflora quadrangularis medic*)

This is the cross of purple and yellow passion fruit developed at Indian institute of Horticulture Research in Karnataka. It is oblong to oval in shape and of a very large size (20-30cm long, 12-15cm diameter). It has greenish white to yellowish sweet acidic pulp juice with mild flavour. Each fruit weighs about 90-110grams, it is the best yielding variety compared to purple and yellow passion fruit and has high degree of tolerance for common pests and diseases.

Source: (Akali and Maiti, 2006).

CLIMATIC REQUIREMENT OF PASSION FRUIT

The purple passion fruit is most suited to subtropical and temperate climates; it grows and produces well between altitudes 650-1300m. It equally grows well in lowland but will flower and fruit only above 1,000m. The yellow passion fruit is tropical or near tropical, it grows and flowers well near sea level up to an elevation of 600m or even higher depending upon proximity to equator (Nakasone and Paull, 1999). Optimum temperatures for production of purple and yellow passion fruit are between 18°C to 25°C and 25°C to 30°C respectively. Although passion fruit plant can successfully grow in temperatures between 18°C and 35°C (Sao- Jose, 1993), lower temperatures delay growth of the plant, reduce nutrients uptake and fruit yield while extremes temperature affect fruit bearing.

Light is also an important factor that helps passion flower vine reach its full height and bloom to its best advantage. These plants prefer full sun and require at least four hours of bright sun each day for best growth. They also need strong light to support full production of their petaled flowers. Light directly influences growth and flowering in passion fruit by inducing

photosynthesis and feeding plant energy. The rate of growth and length of time passion fruit remains active is dependent on the amount of light it receives. An increase in the hours of daylight results in greater photosynthetic activity, increase in plant vigour, size and quality of the fruit. Inadequate light affects flowers and fruit formation (Joy, 2010). As a long day plant, regions where the critical day length is greater than 11hours have the best flowering conditions. The passion flower continuously produces fruits throughout the year in a semi-arid region with more than 11hours of day light associated with high temperatures as long as there is an adequate supply of water. Light intensity greatly influences the phenological phenomenon of flower opening in the yellow passion fruit (Gamarra- Rojas and Medina, 1995). Passion fruit vines are vigorous growers and so vines need adequate moisture particularly while young and when fruits are maturing. Water requirement is high when fruits are approaching maturity. Generally, annual rainfall varies from 900mm to 2000mm and must be well distributed throughout the year, preferably with 60 to 120mm of water each month and may be complemented when necessary with irrigation (Sao- Jose, 1993).

Excess rain during flowering causes poor fruit set because they inhibit pollination by reducing the activity of pollinating insects and causing pollen grains to burst and also encourage diseases, mainly leaf and fruit rust. Although the plant may withstand drought relatively well, prolonged drought damages its vegetative development and in severe cases, causes leaf fall and the formation of smaller and lighter fruits. High or low relative humidity largely affects the vegetative development of phytosanitary state of the passion fruit vine (Borges, *et al.*, 2002). Air relative humidity of about 60% is the most preferable for the passion fruit cultivar. Low relative humidity associated with high temperature and constant wind causes drying out of the plant tissues due to excessive transpiration and this impedes the development of the plant. However, relative humidity above 60% when associated with rains

favours the appearance of diseases like citrus scab, anthracnose (black spot) and bacteriose in the above ground parts of the vine (Borges *et al.*, 2002).

WIND PROTECTION

Passion fruit plants are not naturally hardy plants; they are very sensitive to environmental stress. In their natural rainforest environment, vines are protected from environmental extremes so the choice of site is very essential. Passion fruit grown on an unsuitable site will give a lower yield at a higher cost than those grown on a favourable site.

It is very important that Passion fruits should be sheltered from strong wind because Wind exposure causes stress that significantly reduces the vigour of plant which leads to plant fall, delays growth as well as reducing yield and quality of fruits. In addition, movement of fruit in the wind against vine stems, posts and trellis wires causes rub marks on the fruit, rendering it unsuitable for the fresh market hence the use of windbreaks such as bamboo, eucalyptus and grass species is indispensable (Ruggerro *et al.*, 1998).

SOIL REQUIREMENT OF PASSION FRUIT

Passion fruit plants are susceptible to a number of root diseases associated with wet soil so need to be grown in a well drained soil. Passion fruit can be grown on a wide range of soils. Sandy to clay loams but sandy clay or light to heavy sandy loams with a pH of 6.5 to 7.5 are the most suitable (Morton, 1987, Terxeira, 1995, Cooper *et al.*, 2011). Being a shallow rooted crop (60% of the roots are located within 30cm of the surface), it is important that the root growth is not impeded in the top 60cm. Also the soil should be deep, low in salt, rich in organic matter and well drained. For good growth, it is recommended that the soil has neither impermeable rocky or hardened layers, nor a water table at less than 2m to avoid the appearance of dry rot (Borges *et al.*, 2002).

PROPAGATION

Passion fruit vines are usually grown from seeds; however, the progeny are variable. Cutting is one of the vegetative propagation techniques used in passion fruit plants which contributes to uniform orchards, besides mitigating, in a short-term, pathogen symptoms (Vaz *et al.*, 2009) as well as reducing crop earliness (Lira- Junior, 2012). An easy method of propagation and one that will preserve characteristics of the parent is by layers or cuttings of matured wood with three to four nodes that is well rooted and ready for setting out in 90 days. Rooting may be hastened by hormone treatment and yellow passion fruit is best for production of rootstock for grafting because it helps to perpetuate hybrids and also reduces nematode damage and diseases while the purple vine is good for fruit production. In contrast, this technique is absent of genetic segregation, which is a drawback to passion fruit farming according to (Rezende *et al.*, 2005), since high rates of self-incompatibility require maintenance of genetic variability. Because of such limiting factor, seed propagation takes precedence over the asexual method because it has a shorter waiting period for seedling growth, would decrease viral infections (Correa *et al.*, 2010) and promote a less complex and low-cost seedling production. Report by (Rivera *et al.*, 2002) showed that seed propagation ensures the ease of obtaining vigorous plants with better root formation and more productivity as compared to those propagated asexually. Fresh seeds are far easier to propagate than seeds that are older than a month or two. Seeds should not be exposed to light until they have germinated. Older seeds can be soaked in tea or coffee for at least one day to improve germination. Plants will bear in 2 or 3 years. Seeds planted soon after removal from the fruit pulp and dry will germinate in ten to twenty days, cleaned and stored seeds have a lower viability and slower rate of germination and should be planted within three months of extraction from the fruit (Gitau, 2017). Seed sprouting may be hastened by allowing the pulp to ferment for a few days before separating the seeds or by chipping the seeds or rubbing

them with fine sand paper. Also application of heat treatment to seeds stored for more than two years is a way of reaching acceptable rates of germination (Meletti *et al.*, 2002).

EARLY GROWTH OF PASSION FRUIT

Seed germination starts with the uptake of water by the dry seeds followed by embryo expansion and ends with the elongation of the embryonic axis as the radicle passes through the structures surrounding the embryo. It involves series of changes that occur during the emergence and development of the embryo and all the structures needed for the growth of a normal plantlet under a conducive growing environment. Reports from Huang *et al.*, (2003) and yang *et al.*, (2008) showed that seed germination is the critical stage for species survival. Chemical and physical features of seeds crop influence their germination and emergence, according to Maciel *et al.*, (1997) and Alexander *et al.*, (2008) presence of a hard seed coat prevents water absorption and consequently inhibits germination in passiflora. Seed quality is normally determined by a number of physical and chemical properties of seeds that confer genetic differences in variation within species (Batistella *et al.*, 2002) which involves differences between two or more genetic lines. There is no clear information on the levels of variation in seeds of different species accessions of passion fruit in relation to their germination and emergence rates. The choice of species of crop to plant in any plantation establishment largely depends on the early growth assessment of the crop because if not properly conducted will result to poor yield. Studies by Baiyeri and Mbah, (1994) and Ndukwe *et al.*, (2011) showed that pre-flowering growth parameters in plantain have significant and positive relationship with the final fruit yield. Therefore, early growth assessment of passion fruits will help to determine the final fruit yield in Nsukka agro ecological zone of Nigeria.

CULTURAL REQUIREMENTS IN PASSION FRUIT FARMING

IRRIGATION

Passion fruit vine develops continuously and the root system is small for the size of the plant it has to sustain, it needs a constant supply of water because soil water level influences passion-fruit flowering and fruiting (Vasconcelos, 1994). A lack of moisture results in loss of leaves and fruits, especially at the start of their development, and this affects the production and quality of the fruits (Manica, 1981; Ruggiero *et al.*, 1998). In area where the rains are insufficient or poorly distributed, irrigation is essential, not only to increase productivity but also to improve the quality of the fruit, via continuous and uniform production (Borges *et al.*, 2002, Oliveira *et al.*, 2010). Among other roles, water constitutes 50%–90% of the fresh weight of plants, it enables plants absorb nutrients from the soil, and it is important in plant growth and developmental processes: from cellular through whole plant level (Muthomi and Musyimi, 2009). Because plants water demand vary with season and location, the quantity and quality of water available for optimum crop performance during any growing cycle must be well considered (Jones and Tardieu, 1998). Therefore, irrigation should be provided in the nursery and after transplanting the seedlings from nursery to the field so as to keep moisture level constant, mulch materials should be provided to reduce evaporation as well as control the growth of weeds. Passion fruit roots are wide spreading when watering established vines, soak a wide area in a 3 to 5 m radius from the base of the trunk. Regular watering helps to keep a vine flowering and fruiting almost continuously and water requirement is high when fruits are approaching maturity. In times of extended dryness, water deeply because dry soil will lead to flower and premature fruit drop. Leaf drop at the base of vines can also be another sign of dryness. However, passion fruit cannot handle waterlogged soil thus careful attention must be paid to watering since overwatering can help further detrimental diseases and under watering can leave the shallow roots too dry. Different crop species

respond differently to different soil water levels; from flooded conditions to field capacity on one side, and from field capacity to permanent wilting point on the flipside. Some responses to reduced or deficit soil water conditions include decline in growth rate, leaf area, leaf number, plant height, dry matter accumulation, protein and chlorophyll synthesis, reduced stomata function, transpiration and; increased production of root and stress hormones such as abscisic acid (Menzel *et al.*, 1986; Noogle and Fritz, 1992; Kramer and Boyer, 1995; Muthomi and Musyimi, 2009). These in turn lead to reduced crop yield or crop failure and poor produce quality (Noogle and Fritz, 1992). In passion fruit, moisture deficit (less than - 1.3 MPa) is reported to be the major cause of poor growth, flowering and yield (Paul and Duarte, 2012).

PRUNNING

Passion fruit vines do not need pruning to encourage fruiting but after a vine of either the yellow or purple passion fruit attains two years of age, pruning once a year at any time of the growing season is necessary to keep the vines within bounds, to remove overgrown growth, stimulate new growth and consequently more flower and fruit production. It also makes harvest easier and keeps the plants productive by maintaining vigorous growth. It establishes framework of leaders from which laterals can grow. In areas with cool winters, the best time to prune is in spring as new growth resumes. As a general rule, remove all weak growth and avoid removing main stems, just cut back unwanted twining stems out and some of the denser growth by at least one third to allow better air circulation and fruit development the following season. In very hot climates allow a thick canopy of foliage to grow around the fruit to prevent sunburn. Vines need to be trained and pruned to avoid a tangled mess and to keep flowers accessible to pollinating bees.

FERTILIZATION

Passion fruit vines are vigorous growers that require regular fertilization scheme; vines should be fed with a well-balance all-purpose organic fertilizer at early rainy season to keep plants in good productive health. At planting application of organic and inorganic manures is necessary to ensure vigorous growth with regular and optimum yield. A good choice is 10-5-20 NPK applied at the rate of 1.36 kg per plant 4 times a year (Vieth, 2016). Too much nitrogen results in vigorous foliage growth at the expense of flowering. Passion fruit vines should always be watched for deficiencies, particularly in potassium and calcium, and of less importance, magnesium. Plants that have been damaged by frost should receive a generous fertilizing after the weather has warmed. ; •

TRANSPLANTING

The seedlings should be ready for transplanting about 3 to 6 months after sowing the seed to reach a height of about 30cm to 40cm. Before transplanting side shoots should be removed and root pruned by two weeks. According to NDA (1999) only seedlings with dark green leaves and are free of any symptoms of nematode or fungal diseases infestation will be transplanted. The optimum time for transplanting is during August/September and best done either early morning or late evening. The yellow passion fruit vine is more susceptible to cold than the purple vine and grafted plants should therefore not be planted in areas where frost occurs. Generally plant spacing of 1m to 2m are used. The average lifespan of a healthy passion fruit vine plantation is about three to seven years. Bearing in mind the effect of viruses and soil-borne diseases, plant spacing of about 1m could ensure high production over the short term.

TRELLISING SYSTEM

Trellises are required for the production of passion fruit and should be erected properly in the same direction with the wind wherever possible. A sturdy construction is necessary because it

has to support a heavy mass and the wooden posts must be solid resistant to termites. Trellis rows should be oriented north-south for maximum exposure to sunlight and the vines should be allowed to grow along the trellises to promote cross pollination, support the growing crops and fruit produced. It also ensures that growth is in both directions along the supporting wires.

HIGH TUNNEL

In recent times, passion fruit are not only cultivated in an open field but also in a growing system similar to green house popularly known as high tunnel used in horticultural industries to protect microclimate as well as increasing yields than field crops. High tunnels or hoop houses are temporary, plastic-covered passive solar-heated structures used for growing fruits and vegetables which help commercial farmers extend their growing season so that they can improve the profitability and productivity of their farms (Jiang *et al.*, 2003). High tunnels are an increasingly popular trend for growers and a proven technology for crop production that could come in many different shapes, sizes, and structures. Being an integral part of local food production systems in many parts of the world, they aid fruit and vegetable crop production by extending the cropping season, providing protection from harsh environmental elements (wind, storms, etc.), modifying the environment to improve crop quality and reducing incidence of plant pest and diseases which result in a more-stable production system that poses less risk of crop failure. Therefore, this system protects the crop, lengthens the growing season, and therefore increasing economic impact for the grower (Carey et al, 2009). Despite its benefits, high tunnel growing system requires high initial cost, maintenance of structures, increased manual labour requirement and insect pressure.

Mineral Nutrition and Nutrient uptake in passion fruit

Plants take up nutrients from the soil in the forms of ions but when these nutrients are present in other forms rather than their ionic forms, they become fixed and unavailable for plant use.

Passion fruit thrives well on soils rich in nutrients more especially nitrogen, phosphorus and potassium throughout the growing season and the amount of these nutrients vary at their various stages of growth. (Mello, 2016). It was reported that weightier and sweeter fruits were obtained from plants that received large amounts of potassium, and that the application of potassium increases soluble solids of fruits (Valdez, 2012). In addition, organic manures such as FYM/compost, poultry manure, and neem cake can be added in the planting holes (Joy, 2010).

At all stages of growth and development passion fruit requires adequate nutritional state. To ensure optimum productivity and quality, broad spectrum nutrition including calcium, magnesium and trace elements must be maintained and this requires a fertilization plan to permit the maintenance of an adequate nutritional state of the crop. Excessive nitrogen causes excessive vegetative growth and premature fruit drop, and passion fruit should always be monitored for deficiencies, particularly in potassium and calcium. From the start of fruit formation there is a great demand for energy by the plant and a strong translocation of nutrients from the leaves to the developing fruits and this reduces the vegetative growth of the plant (Borges *et al.*, 2002). Adequate calcium and boron are essential for flowering and pollination. Adequate potassium is critical throughout fruit fill and for optimum fruit-sizing. Phosphorus (P): In its absence passion-fruit growth is reduced, affecting the quantity of dry matter, root growth and fruit production (Manica, 1981; Baumgartner, 1987). Therefore, Phosphorus and potassium should be kept up to maintain the growth of the fruit while calcium will build crop resilience, help in fruit tissue development and strengthening of the cover of the fruit (Mello, 2016).

Passion fruit requires frequent application of balanced fertilizer during its growing season. In winter plants may be chlorotic (yellow between the veins of leaves) due to cold soil

temperatures. Passion fruit require more potassium fertilizer but produce leafy growth and few fruits if given too much nitrogen (Borges *et al.*, 2002, Joy, 2010).

Nutritional Value of Passion Fruit

A wide range of health benefits attributed to passion fruit is due to the nutrient, mineral, and vitamin content of the fruit which include antioxidants, flavonoids, vitamin A, vitamin C, riboflavin, niacin, iron, magnesium, phosphorus, potassium, copper, fiber, and protein. The percentages of many of the vitamins and minerals are very high such that it can result in a number of amazing health benefits.

Health Benefits of Passion Fruit

Immune System: Passion fruit helps to boost body immune system due to vitamin C, carotene and cryptoxanthin it contains. In fact, a single service of passion fruit has more than 100% of the total required intake of vitamin C for a healthy diet (Decuypere, 2000). All of these vitamins act as antioxidants, which scavenge free radicals from the body and neutralize them before they can harm the organs and result in conditions like cancer, heart disease, or premature aging. (Khalid *et al.*, 2004). Furthermore, vitamin C stimulates the activity of white blood cells and the rest of the immune defense system, thereby protecting the body from common illnesses and serious diseases at the same time.

Cancer Prevention: In a related note to the immune system health, passion fruit is also a powerful source of anti-carcinogenic activity in the body. Antioxidants in passion fruit primarily eliminate free radicals which are known for mutating the DNA of healthy cells into cancerous ones (Devi, R.S. *et al.*, 2013). Passion fruit also contains vitamin A, various flavonoids, and phenolic compounds, all of which have been linked to anti-cancer properties, particularly in terms of oral and lung cancers.

Vitamin-A Content: Aside from its cancer-protective qualities, vitamin A is also prevents macular degeneration, cataracts, and night blindness (Bradtke, 2010). Furthermore, this high antioxidant content of passion fruit helps in reducing wrinkles, boost the health and richness of the skin, and promotes the proper functioning of membranes to keep it hydrated.

Digestive Health: Passion fruit is a good source of soluble fiber, which acts as a bulk laxative, moving food through the digestive tract and reducing exposure time of the colon to any toxins. It can reduce signs of constipation by regulating bowel movements, scrubs the blood vessels clean of excess cholesterol, and even prevent gastrointestinal conditions like colorectal cancer (Devi, R.S.*et al.*, 2013).

Blood Pressure: Passion fruit supplies potassium needs in the body immediately to keep the heart healthy and cells functioning. Potassium is a vital mineral in the human body for a number of reasons, one of which is its role as a vasodilator. It relaxes the tension of blood vessels and promotes increased blood flow. This reduces the strain on the heart and increases overall cardiovascular health (Saminu, 2016). Furthermore, potassium is necessary to maintain the proper fluid balance of the body's cells. Movement between membranes is often only allowed through potassium-regulated channels, so proper amounts of this mineral are of extreme importance.

Improved Circulation; According to Saminu, (2016) the high iron and copper content of passion fruit which are both essential components of red blood cell production when combined with the vasodilating properties of potassium, allow free flow of oxygenated blood to necessary areas of the body stimulating the metabolic activity in all the organs thereby boosting productivity and efficiency.

Bone Health and Mineral Density: Since passion fruit is such a rich source of minerals like iron, copper, magnesium, and phosphorus, it is a very important fruit for increasing mineral

bone density and bone strength. Some of these minerals are integral parts in creating additional bone matter, strengthening existing bone matter, and speeding up repair (Annette, 2016). This can be a means of eliminating, preventing, or alleviating the symptoms of osteoporosis and the associated pain and inflammation that occurs when bones deteriorate with age and activity.

Respiratory Conditions and Asthma: Recent studies have shown that a combination of various extracts from the purple passion fruit peel creates a novel mixture of bioflavanoids, which have an expectorant, sedative, and soothing effect on the respiratory system. It has been positively connected to a reduction in asthma attacks, wheezing, and whooping cough (Diposkan, 2015).

MATERIALS AND METHODS

Two field experiments were carried out in the Department of Crop Science Teaching and Research Farm and laboratory of University of Nigeria, Nsukka located in the derived savannah zone at Latitude 06° 25'N, longitude 07° 24'E and altitude 550m above sea level.

Experimental site

An area of land measuring 20m x 20m was cleared and partitioned into two, one portion was used for the construction of a high tunnel (12m x 8m, 2m height) with strong wood and covered with transparent roofing polyethylene sheets; leaving about 1.5 meters on both sides open to aid ventilation while the other piece was used as a control (open field).

Soil sample and seed collection

The experimental soil was collected from a bush re-growth location within the Research Farm at different points at a depth of 0-15cm. Seeds of the yellow varieties (conventional and hybrid) for the experiment were extracted from the fruits of the two genotypes of passion fruit provided by Dr. Emeka Ndukwe of the Department of Crop Science, Nnamdi Azikwe University Awka while the purple seeds were sourced from Nairobi, Kenya through Professor K.P. Baiyeri of the Department of Crop Science, University of Nigeria, Nsukka. The seeds were soaked in sterile water for twenty-four hours, rinsed with distilled water and air dried for two hours before planting in a perforated 30cm high 11-litre plastic buckets filled with garden soil to a height of 27cm leaving 3cm height from the brim for easy application of inorganic manure and irrigation water.

Experiment1: Effects of environment and three rates of potassium fertilizer on the growth pattern of three genotypes of passion fruits (Conventional, Kenya and Purple)

A potted experiment was conducted to study the influence of environment on the growth pattern of three genotypes of passion fruits. Top soil was used as planting medium filled in 180 11- litre pots leaving 2 cm clearance height from the brim. The experimental design was a 2 x 3 x3 split plot arranged in completely randomised design and replicated ten times. The main plots comprised of two different environments namely high tunnel and open field while the sub- plots consisted of three genotypes of passion fruits (purple, conventional and KPF-4). Five seeds of each genotype were directly sown into the plastic pots and later thinned to one seedling per pot at six weeks after planting. The 180 potted seedlings were arranged in a single row and spaced out at 50cm by 50cm inside the tunnel for three months. Thereafter, 30 potted seedlings from each genotype were taken to the open field. Treated bamboo sticks about 3m length were used as trellis; five bamboo poles were used to support a single row of ten plants such that a pole was placed in between two plants. At one month after transplanting, seedlings under the high tunnel and in the field received varying potassium fertilizer (Muriate of potash 60% K_2O) equivalent rates of 0kg K_2O /ha, 100kg K_2O /ha, and 200kg K_2O /ha. Data on growth parameters were collected at one- month intervals after treatment application; they included number of unifoliate, bifoliate and trifoliate leaves by count, length of tallest vine with meter tape and number of branches by visual counts. Thereafter, one third of the plant population in each genotype of both environments was destroyed at eight weeks after treatment application to assess fresh and dry weight of each genotype.

Experiment 2: Evaluation of environment and three rates of potassium fertilizer on yield, juice quality and post harvest quality of three genotypes of passion fruit

The objective of this study was to assess fruit yield, juice quality and post harvest quality of conventional, KPF-4 and purple genotypes of passion fruit. The seedlings inside the high tunnel and in the open field at the onset of bud formation received second dose of 0kg/ha, 100kg/ha, and 200kg/ha potassium fertilizer. Each potassium fertilizer rate was applied as top dressing in each pot containing the seedlings for each genotype. The 180 plastic pots were arranged in a 2 x 3 x 3 split-split experiment in completely randomized design representing two different environments, (high tunnel and open field), three rates of potassium (0, 100 and 200kg/ha) and three genotypes (purple, conventional and KPF-4). The genotypes were evaluated for growth and dry matter yield. Each genotype was replicated ten times which formed the sub-plots while the varying rates of potassium fertilizer represented the sub-sub-plots. One third of the plant population in each genotype of both environments was destroyed at 4 months after treatment application to assess dry matter accumulation and partitioning to the above ground components. Data collected included fresh leaf and vine weights of pruned branches with their corresponding dry weights after oven-drying, and percentage moisture content of leaf and vine. Fruit yield data collected included number of fruits picked, weight of fresh fruit, length and circumference of fruit, weight of seeds, rind thickness with digital vernier callipers, percentage fruit weight loss and volume of fruit juice. All the weights were measured with digital weighing balance.

Biochemical analysis of passion fruit

To ascertain juice quality, harvested fruits were subjected to biochemical analysis to determine the proximate, mineral, vitamin and phytochemical compositions of the fruit juice.

Statistical analysis

All the data collected from this study were subjected to analysis of variance (ANOVA) following the procedure of split-split plot experiment in a completely randomised design using Genstat 10.3 edition. Differences among treatment means for significance were detected using Fisher's least significance differences (F-LSD) test at 5% probability level as described by Obi (2002).

RESULTS

EXPERIMENT 1

GROWTH RESPONSES OF PASSION FRUITS AS INFLUENCED BY GENOTYPES, ENVIRONMENT AND POTASSIUM FERTILIZER

Table 1 shows the main effects of the environment on the three genotypes of passion fruit under the high tunnel and in the field. The data in the table revealed that environment significantly ($p < 0.05$) influenced number of unifoliate leaves, number of branches and vine length at varying months after treatment application. Number of unifoliate leaves was significantly different at one, two and seven months and statistically similar at three, four, five and six months after treatment application. However, higher number of unifoliate leaves was observed in the field with the highest value 42.2 at 2MATA compared to high tunnel that gave the least value 12.7 at 3MATA. Although number of bifoliate and trifoliate leaves were statistically similar ($P > 0.05$) in both environments in all the months, bifoliate leaves and trifoliate leaves were more in the high tunnel with higher mean values of 10.61 and 64.2 at 5 MATA, respectively.

Number of branches showed significant differences between the two environments at one and three months and statistically similar ($P > 0.05$) at other months. The highest values were seen in the field 10.8 at 6MATA than in the high tunnel 2.6 at 1MATA. Vine length significantly differed between the two environments in all the months. Precisely, longer vines were associated with plants inside the tunnel with highest value 300.9 cm at 6 MATA than in the field with least value 105.6 cm at 2MATA.

Table 1: Main effect of environment on growth parameters of passion fruit at different Months after treatment application

ENVIR	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA					
FIELD	37.1	2.6	9.8	3.0	105.7
HIGH TUNNEL	25.3	1.8	11.3	2..6	125.8
LSD_(0.05)	4.4	NS	NS	0.2	17.3
2MATA					
FIELD	42.2	2.9	14.3	4.0	105.7
HIGH TUNNEL	28.6	3.1	22.4	3.4	167.9
LSD_(0.05)	0.8	NS	NS	NS	9.4
3MATA					
FIELD	14.3	2.9	11.3	1.7	107.0
HIGH TUNNEL	12.7	2.7	22.1	2.8	216.5
LSD_(0.05)	NS	NS	NS	0.996	11.6
4MATA					
FIELD	31	4.7	24.4	4.2	125.6
HIGH TUNNEL	24.6	6.1	45.0	5.6	256.9
LSD_(0.05)	NS	NS	NS	NS	26.8
5MATA					
FIELD	34.5	4.8	45	6.2	150.1
HIGH TUNNEL	26.8	10.6	64.2	7.2	295.6
LSD_(0.05)	NS	NS	NS	NS	88.3
6MATA					
FIELD	33.0	3.4	52.5	10.8	166.6
HIGH TUNNEL	23.1	3.3	38.8	9.3	300.9
LSD_(0.05)	NS	NS	NS	NS	86.9
7MATA					
FIELD	35.8	5.6	59.4	7.3	181.0
HIGH TUNNEL	23.2	2.9	24.1	9.2	281.1
LSD_(0.05)	8.5	NS	NS	NS	86.8

ENVIR= Environment, BIFL= Bifoliate-leaves, BRCH=Branches, TRFL=Trifoliate-leaves, UNIFL=Unifoliate-leaves, VINL=Vine-length; MATA =Months after treatment application.

Table 2: shows the effect of genotype on growth pattern of passion fruit at different months after treatment application.

The growth parameters significantly ($p < 0.05$) differed among the three genotypes at some months. Number of unifoliate, bifoliate and trifoliate leaves varied with the genotypes at 1, 4 and 5 MATA respectively. The genotype KPF-4 had greater number of unifoliate and bifoliate leaves with the mean values 71.3 and 10.6 at 7 and 5 MATA while purple had lesser number of both leaves with mean values of 3.33 and 0.83 at 7 and 6 MATA.

On the other hand, purple genotype at 5 MATA showed greater number of trifoliate leaves with mean value of 67.2. Genotype significantly influenced number of branches across the months except at 6 MATA. Highest number of branches was associated with the KPF-4 at five months while purple genotype produced the least at three months. Vine length showed significant difference among the genotypes across the months. At 6 MATA, the hybrid KPF-4 produced longest vine with mean value of 260.6 cm compared to purple genotype that had shortest vine with mean value of 85.5 cm at 1 MATA.

Table 2 shows the Main effect of genotype on growth parameters of passion fruit at different months after treatment application

GENOTYPE	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA					
CONV	29.8	1.8	7.9	2.3	129.9
KPF-4	40.7	2.0	3.5	2.7	131.8
PURPLE	23.3	2.9	20.2	3.6	85.5
LSD_(0.05)	6.0	0.8	3.0	0.9	12.8
2MATA					
CONV	34.6	2.6	14.6	3.2	149.6
KPF-4	47.4	3.2	7.9	3.6	155.7
PURPLE	24.3	3.3	33.0	4.2	105.1
LSD_(0.05)	0.8	NS	4.4	0.6	9.7
3MATA					
CONV	13.7	2.1	15.7	2.0	186.1
KPF-4	22.1	4.3	11.6	3.1	173.7
PURPLE	4.7	2.1	22.8	1.7	125.4
LSD_(0.05)	NS	NS	5.0	0.8	11.3
4MATA					
CONV	24.9	5.78	32.3	4.33	194.8
KPF-4	54.2	8.61	26.8	6.72	214.4
PURPLE	4.3	1.78	44.8	3.61	164.5
LSD_(0.05)	8.9	2.5	13.8	1.6	22.2
5MATA					
CONV	20.7	5.4	53.4	5.9	234.8
KPF-4	65.1	10.6	43.2	8.8	240.1
PURPLE	6.2	1.4	67.2	5.4	193.6
LSD_(0.05)	13.6	1.9	16.4	1.3	23.9
6MATA					
CONV	12.6	2.4	43.6	11.6	241.1
KPF-4	68	6.8	41.3	13.1	260.6
PURPLE	3.6	0.8	52.1	5.4	199.6
LSD_(0.05)	16.7	2.9	NS	NS	25.3
7MATA					
CONV	13.9	3.8	44.1	7.2	256.2
KPF-4	71.3	8.1	44.1	12.6	243.5
PURPLE	3.3	0.9	37.1	4.8	193.4
LSD_(0.05)	10.4	2.5	NS	2.1	24.4

Table 3 shows the effect of potassium fertilizer rates on growth parameters of three genotypes of passion fruits grown in open field and high tunnel

Different potassium fertilizer rates applied showed no significant differences ($p > 0.05$) for the growth parameters except for the number of trifoliate leaves, which significantly varied at one, two and four months after treatment application, with mean values of 11.9, 21.6 and 44.7, respectively. Although number of unifoliate and bifoliate leaves as well as number of branches and vine length were statistically similar ($p > 0.05$) across the months, greater number of bifoliate leaves were observed on plants that received 200kg/ha of potassium fertilizer at 5MATA while 100kg/ha gave higher number of unifoliate leaves and branches at 2 and 6MATA, respectively (Table 3). At 7 MATA, longest vines were recorded on plants that received 100kg/ha while 200kg/ha at 5MATA gave greater number of trifoliate leaves which were statistically similar to other potassium fertilizer levels.

Table 4 shows the combined effects of environment and fertilizer on the growth response of three genotypes of passion fruit

The results of the interaction (Table 4) revealed that all the growth parameters were statistically similar across the months except number of trifoliate leaves that showed significance ($P < 0.05$) at 2 MATA. Plants under the high tunnel that received 100kg/ha of potassium fertilizer produced higher number of trifoliate leaves with mean value of 23.33 while lesser number was associated with plants in the field with no fertilizer. Vine length was at an increase with plants kept inside the high tunnel than those in the field

Table 3: Main effect of potassium Fertilizer on growth parameters of passion fruit at different months after treatment application

FRTLZR	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA					
0	30.7	1.8	8.2	2.8	113.8
100	30.8	2.7	11.4	2.7	117.1
200	32	2.3	11.9	3.0	116.2
LSD_(0.05)	NS	NS	2.6	NS	NS
2MATA					
0	34.7	2.3	14.7	3.7	132.4
100	37.6	3.3	18.7	3.7	140.5
200	33.9	3.4	21.6	3.6	137.4
LSD_(0.05)	NS	NS	4.4	NS	NS
3MATA					
0	15.1	2.4	14.7	2.2	161.6
100	13.7	2.0	16.4	1.9	163.7
200	11.7	4.0	19.1	2.7	160.0
LSD_(0.05)	NS	NS	NS	NS	NS
4MATA					
0	33	6.2	25.7	4.4	189.4
100	26	3.9	33.6	4.6	184.9
200	23.9	6.0	44.7	5.6	199.4
LSD_(0.05)	NS	NS	13.78	NS	NS
5MATA					
0	34.3	4.8	44.9	6.06	210.7
100	31.9	5.8	55.1	7.0	230.6
200	25.8	6.9	63.8	7.1	227.3
LSD_(0.05)	NS	NS	NS	NS	NS
6MATA					
0	32.9	2.9	38.5	8.5	218.6
100	30.3	4.5	49.2	13.6	247.6
200	20.9	2.6	49.2	8.0	235.1
LSD_(0.05)	NS	NS	NS	NS	NS
7MATA					
0	36.9	4.1	37.1	8.8	227.9
100	30.3	5.7	40.2	8.8	255.1
200	21.2	3.1	47.9	7.1	210.1
LSD_(0.05)	NS	NS	NS	NS	NS

BIFL= Bifoliate leaves, BRCH=Branches, TRFL=Trifoliate leaves, UNIFL=Unifoliate leaves, VINL=Vinelength; MATA =Months after treatment application.

Table 4: Main effect of environment and fertilizer interaction on the growth parameters of passion fruit at different months after treatment application

ENVIR	FERTIIZER	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA						
FIELD	0	37.4	2.2	5.7	3	103.8
FIELD	100	35.2	2.9	11.6	2.7	106.6
FIELD	200	38.6	2.9	12.1	3.4	106.7
HIGH TUNNEL	0	24.0	1.3	10.8	2.7	123.9
HIGH TUNNEL	100	26.3	2.4	11.3	2.7	127.8
HIGH TUNNEL	200	25.4	1.7	11.7	2.6	125.7
LSD_(0.05)		NS	NS	NS	NS	NS
2MATA						
FIELD	0	43.8	2	7.7	4.2	98.7
FIELD	100	44.6	3.1	14.2	3.9	110.7
FIELD	200	38.3	3.8	20.9	3.9	107.6
HIGH TUNNEL	0	25.3	2.6	21.7	3.2	166.2
HIGH TUNNEL	100	25.5	3.6	23.2	3.6	170.3
HIGH TUNNEL	200	22	3.1	22.2	3.3	167.2
LSD_(0.05)		NS	NS	9.19	NS	NS
3MATA						
FIELD	0	17.2	2.9	7.7	1.4	105.7
FIELD	100	13.6	1.6	9.7	1.4	103.3
FIELD	200	12.0	4.1	16.7	2.2	112.1
HIGH TUNNEL	0	12.9	1.9	21.7	3.0	217.6
HIGH TUNNEL	100	13.8	2.4	23.1	2.3	224.0
HIGH TUNNEL	200	11.4	3.9	21.4	3.1	207.9
LSD_(0.05)		NS	NS	NS	NS	NS
4MATA						
FIELD	0	38.1	6.4	14.8	4.0	126.4
FIELD	100	30.2	3.2	20.9	3.7	121.7
FIELD	200	24.7	4.4	37.4	4.8	128.7
HIGH TUNNEL	0	27.9	6.0	36.6	4.9	252.3
HIGH TUNNEL	100	22.9	4.7	46.3	5.6	248.1
HIGH TUNNEL	200	23.1	7.6	52	6.4	270.1
LSD_(0.05)		NS	NS	NS	NS	NS

Table 4
Contiued

ENVIR	FERTIIZER	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
5MATA						
FIELD	0	40.9	4.1	35.6	6.2	142.2
FIELD	100	35.6	4.8	39.8	5.6	157
FIELD	200	27.2	5.6	59.6	6.8	151
HIGH						
TUNNEL	0	27.8	5.6	54.2	5.9	279.1
HIGH						
TUNNEL	100	28.3	6.8	70.3	8.4	304.1
HIGH						
TUNNEL	200	24.3	8.2	68	7.3	303.7
LSD_(0.05)		NS	NS	NS	NS	NS
6MATA						
FIELD	0	37.1	3.11	44.6	7.3	161.9
FIELD	100	36.8	4.11	48.8	17.6	175.1
FIELD	200	25.1	3.0	64.2	7.6	162.7
HIGH						
TUNNEL	0	28.8	2.8	32.7	9.7	275.3
HIGH						
TUNNEL	100	23.8	4.9	49.7	9.7	320
HIGH						
TUNNEL	200	16.8	2.2	34.1	8.4	307.4
LSD_(0.05)		NS	NS	NS	NS	NS
7MATA						
FIELD	0	42.7	5.3	58.9	7.4	178.6
FIELD	100	41.7	7.7	52.7	7.0	196.3
FIELD	200	23	3.8	66.8	7.3	168.1
HIGH						
TUNNEL	0	31.1	2.8	15.3	10.1	277.3
HIGH						
TUNNEL	100	19	3.7	27.8	10.6	313.8
HIGH						
TUNNEL	200	19.4	2.3	29.1	6.8	252.1
LSD_(0.05)		NS	NS	NS	NS	NS

BIFL= Bifoliate leaves, BRCH=Branches, TRFL=Trifoliate leaves, UNIFL=Unifoliate leaves, sVINL=Vinlength; MATA =Months after treatment application.

Table 5 shows the interaction effects of environment and genotype on the growth parameters at different months after potassium fertilizer application

Interaction of genotypes and environment for some growth parameters were significant ($P < 0.05$) or non significantly ($P > 0.05$) different across the varying months (Table 5). The hybrid KPF-4 inside the high tunnel produced higher number of unifoliate leaves at 3 and 4 MATA with mean values of 24.8 and 57.1 respectively, compared to purple that had lesser number with mean values of 2.6 and 2.7, respectively.

At 2, 4, 5 and 6 MATA, number of bifoliate leaves varied significantly, greater number were observed on the hybrid KPF-4 under the high tunnel with mean values of 4.3, 12.4, 15.7 and 8.9 while purple under the same environment gave lesser number at those months except at two months when KPF-4 in the field produced lesser number with mean value of 2.11.

However, vine length and number of trifoliate leaves showed significant difference at 6 and 7 MATA. Purple genotype in the field had highest number of trifoliate leaves with mean value of 63.7 compared to conventional under the tunnel that gave the least with mean value of 27.8. At 7 MATA, conventional genotype in the field produced greater number of trifoliate leaves with a mean value of 12.1 respectively.

Number of branches significantly ($P < 0.05$) differed across 3, 4, 5 and 7 MATA. KPF-4 genotype under the high tunnel was consistently at an increase with mean values of 4.3, 8.7, 10.4 and 16.3 compared to conventional and purple in the field with mean values of 1.6 and 3.6 as well as purple under the tunnel with mean values of 5.1 and 3.6. Similarly, longer vines were noticed on the hybrid KPF-4 inside the tunnel with mean values of 328.7 cm and 281.9 cm at 6 and 7 MATA.

Table 5: Effects of environment and genotype interactions on the growth parameters of passion fruit at different months after treatment application

ENVIR	GENOTYPE	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA						
FIELD	CONV	35.7	2.0	6.9	2.3	118.6
FIELD	KPF-4	48.0	2.2	3.1	2.8	121.9
FIELD	PURPLE	27.6	3.8	19.3	4.0	76.6
HIGH TUNNEL	CONV	23.9	1.7	8.9	2.2	141.2
HIGH TUNNEL	KPF-4	33.3	1.8	3.9	2.6	141.7
HIGH TUNNEL	PURPLE	18.6	2.0	2.1	3.1	94.4
LSD_(0.05)		NS	NS	NS	NS	NS
2MATA						
FIELD	CONV	41.9	2.44	9.2	3.7	116.4
FIELD	KPF-4	54.3	2.11	4.1	3.7	122.3
FIELD	PURPLE	30.4	4.33	29.4	4.7	78.1
HIGH TUNNEL	CONV	27.2	2.67	18.9	2.8	182.7
HIGH TUNNEL	KPF-4	40.4	4.33	11.7	3.6	189.1
HIGH TUNNEL	PURPLE	18.1	2.22	36.6	3.8	132
LSD_(0.05)		NS	1.42	NS	NS	NS
3MATA						
FIELD	CONV	16.6	1.7	9.1	1.6	125.9
FIELD	KPF-4	19.4	4.2	5.8	1.9	122.1
FIELD	PURPLE	6.8	2.7	19.1	1.7	73.1
HIGH TUNNEL	CONV	10.8	2.4	22.3	2.4	246.3
HIGH TUNNEL	KPF-4	24.8	4.3	17.3	4.3	225.3
HIGH TUNNEL	PURPLE	2.6	1.4	26.6	1.7	177.8
LSD_(0.05)		8.1	NS	NS	1.03	NS
4MATA						
FIELD	CONV	35.7	7.2	19.6	4.1	142.3
FIELD	KPF-4	51.3	4.6	11	4.8	142.7
FIELD	PURPLE	6.0	2.3	42.6	3.6	91.8
HIGH TUNNEL	CONV	14.1	4.3	45.1	4.6	247.2
HIGH TUNNEL	KPF-4	57.1	12.7	42.7	8.7	286.1
HIGH TUNNEL	PURPLE	2.7	1.2	47.1	3.7	237.2
LSD_(0.05)		13.71	4.6	NS	2.2	NS

Table 5 Continued

ENVIR	GENOTYPE	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
5MATA						
FIELD	CONV	30.2	6.2	46	5.8	170.1
FIELD	KPF-4	65	5.6	23.2	7.1	168.4
FIELD	PURPLE	8.3	2.7	65.7	5.7	111.7
HIGH						
TUNNEL	CONV	11.2	4.7	60.8	6.1	299.6
HIGH						
TUNNEL	KPF-4	65.1	15.7	63.1	10.4	311.8
HIGH						
TUNNEL	PURPLE	4.1	0.2	68.7	5.1	275.6
LSD_(0.05)		NS	3.4	NS	1.7	NS
6MATA						
FIELD	CONV	21.4	4	59.4	17.7	191
FIELD	KPF-4	71	4.8	34.4	8.7	192.4
FIELD	PURPLE	6.6	1.4	63.7	6.1	116.2
HIGH						
TUNNEL	CONV	3.7	0.8	27.8	5.6	291.2
HIGH						
TUNNEL	KPF-4	65	8.9	48.1	17.4	328.7
HIGH						
TUNNEL	PURPLE	0.7	0.2	40.6	4.8	282.9
LSD_(0.05)		NS	3.7	27.1	NS	68.6
7MATA						
FIELD	CONV	21.4	6.3	72.1	6.9	220.3
FIELD	KPF-4	79.6	8.7	44.1	8.9	205.1
FIELD	PURPLE	6.3	1.8	62.1	6	117.6
HIGH						
TUNNEL	CONV	6.3	1.3	16	7.4	292
HIGH						
TUNNEL	KPF-4	63	7.4	44.1	16.3	281.9
HIGH						
TUNNEL	PURPLE	0.2	0	12.1	3.67	269.3
LSD_(0.05)		NS	NS	43.7	3.7	68.4

BIFL= Bifoliate leaves, BRCH=Branches, TRFL=Trifoliate leaves, UNIFL=Unifoliate leaves, VINL=Vinelength; MATA =Months after treatment application.

Table 6 shows the effects of genotype and potassium fertilizer interaction on growth parameters of passion fruit at different months under the high tunnel and in the field

The combined effect of genotype and levels of potassium fertilizer on the growth parameters (Table 6) revealed that only vine length was significantly ($p < 0.05$) different at 2 and 3 MATA. The hybrid KPF-4 with 200kg/ha potassium fertilizer produced longer vines at 2 months with mean value 167.2cm while the conventional genotype with no potassium fertilizer gave higher value of 200cm at 3 months. However, purple genotype without potassium fertilizer and that with 200kg/ha had the shortest vine length at both months with mean values of 97.3cm and 109.8cm, respectively.

Unifoliate, bifoliate, trifoliate leaves as well as branches were statistically similar across the months. At Five months, KPF-4 genotype that received 200kg/ha produced highest number of bifoliate and trifoliate leaves 11.8 and 76.5 while conventional with 100kg/ha had highest number of branches with a mean value of 23.8.

Table 6: Effect of genotype and fertilizer interactions on the growth parameters of passion fruit at different months after treatment application

GENOTYPE	FERTIIZER	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
1MATA						
CONV	0	26.0	1.0	7.5	2.2	136.0
KPF-4	0	42.0	1.3	2.3	2.8	126.7
PURPLE	0	24.2	3.0	14.8	3.5	78.8
CONV	100	31.7	2.3	6.7	2.0	127.7
KPF-4	100	38.0	2.8	4.3	2.5	132.7
PURPLE	100	22.7	2.8	23.3	3.5	91.2
CONV	200	31.7	2.2	9.5	2.7	126.0
KPF-4	200	42.0	1.8	3.8	2.7	136.0
PURPLE	200	22.3	2.8	22.3	3.7	86.5
LSD_(0.05)		NS	NS	NS	NS	NS
2MATA						
CONV	0	31.0	1.2	12.2	2.8	157.8
KPF-4	0	47.8	2.5	6.7	4.0	142.2
PURPLE	0	25.3	3.2	25.2	4.3	97.3
CONV	100	40.5	3.2	12.5	3.5	150.0
KPF-4	100	46.7	3.5	5.3	3.2	157.8
PURPLE	100	25.5	3.3	38.3	4.5	113.7
CONV	200	32.2	3.3	17.5	3.3	140.8
KPF-4	200	47.7	3.7	11.7	3.7	167.2
PURPLE	200	22.0	3.3	35.5	3.8	104.2
LSD_(0.05)		NS	NS	NS	NS	15.7
3MATA						
CONV	0	15.2	1.3	15.3	2.3	200.0
KPF-4	0	23.2	2.2	9.3	3.2	159.7
PURPLE	0	6.8	3.7	19.3	1.2	125.2
CONV	100	16.0	1.8	13.2	1.5	175.2
KPF-4	100	20.2	3.2	8.8	2.5	174.5
PURPLE	100	4.8	1.0	27.2	1.7	141.3
CONV	200	9.8	3.0	18.7	2.2	183.2
KPF-4	200	23.0	7.5	16.5	3.7	187.0
PURPLE	200	2.3	1.5	22.0	2.2	109.8
LSD_(0.05)		NS	NS	NS	NS	20.4
4MATA						
CONV	0	32.2	8.5	31.3	5.0	213.2
KPF-4	0	62.5	8.3	17.0	6.0	190.2
PURPLE	0	4.3	1.8	28.7	2.3	164.8
CONV	100	26.8	4.5	30.8	4.5	170.2
KPF-4	100	50.0	6.3	19.5	5.7	209.5
PURPLE	100	2.8	1.0	50.5	3.7	175.0
CONV	200	15.7	4.3	34.8	3.5	201.0
KPF-4	200	50.2	11.2	44.0	8.5	243.5
PURPLE	200	5.8	2.5	55.3	4.8	153.7
LSD_(0.05)		NS	NS	NS	NS	NS

Table 6
Continued

GENOTYPE	FERTIIZER	UNIFL(n)	BIFL(n)	TRFL(n)	BRCH(n)	VINL(cm)
5MATA						
CONV	0	20.7	5.7	58.0	6.0	239.5
KPF-4	0	75.2	6.8	27.7	7.8	199.0
PURPLE	0	7.2	2.0	49.0	4.3	193.5
CONV	100	27.0	5.3	44.3	6.0	242.0
KPF-4	100	63.3	11.2	44.8	9.3	245.0
PURPLE	100	5.3	0.8	76.0	5.7	204.7
CONV	200	14.5	5.3	57.8	5.8	223.0
KPF-4	200	56.7	11.8	57.0	9.2	276.3
PURPLE	200	6.2	1.5	76.5	6.2	182.7
LSD _(0.05)		NS	NS	NS	NS	NS
6MATA						
CONV	0	13.0	1.8	38.2	5.5	248.0
KPF-4	0	81.3	6.2	29.0	15.7	216.0
PURPLE	0	4.5	0.8	48.7	4.3	191.8
CONV	100	17.7	4.3	50.5	23.8	245.2
KPF-4	100	71.5	8.7	39.5	11.8	279.2
PURPLE	100	1.7	0.5	57.7	5.2	218.3
CONV	200	7.0	1.0	42.2	5.5	230.3
KPF-4	200	51.2	5.7	55.3	11.7	286.5
PURPLE	200	4.7	1.2	50.0	6.8	188.5
LSD _(0.05)		NS	NS	NS	NS	NS
7MATA						
CONV	0	13.8	4.0	38.7	6.5	263.8
KPF-4	0	92.2	7.0	31.8	15.8	226.3
PURPLE	0	4.7	1.2	40.8	4.0	193.7
CONV	100	21.2	4.5	45.8	8.2	263.2
KPF-4	100	65.8	11.0	34.0	12.7	282.2
PURPLE	100	4.0	1.5	40.8	5.5	219.8
CONV	200	6.7	3.0	47.7	6.8	241.5
KPF-4	200	55.8	6.2	66.5	9.3	222.0
PURPLE	200	1.2	0.0	29.7	5.0	166.8
LSD _(0.05)		NS	NS	NS	NS	NS

Table 7 shows the main effects of environment, genotypes and potassium fertilizer on fresh-weight, dry-weight and moisture content of passion fruit

Environment did not show significant ($p>0.05$) difference on fresh and dry weight of the plants (Table 7). Although plants under the high tunnel had higher values of fresh and dry weight, moisture content was higher in those grown in the field.

Genotypes significantly ($p<0.05$) influenced both fresh and dry weight but statistically similar on moisture content. Purple genotype had the highest mean values of 96.6 g and 23.0 g of both weights compared to conventional genotype that gave the least values of 69.0g and 16.0g, respectively.

Application of potassium fertilizer rates showed significant difference on fresh weight and moisture content. Plants that received 100kg/ha potassium fertilizer gave higher value 92.6g of fresh weight while those plants without fertilizer had the lesser value of 71.8g. Moisture content was highest on plants that received 200kg/ha than those with no fertilizer. Dry weight was statistically similar in plants with different fertilizer levels yet plants with 100kg/ha gave higher value of 21.3g.

Table 7: Main effects of genotype, environment and potassium fertilizer on the fresh weight, dry weight and moisture content of three genotypes of passion fruit

ENVIRNMENT	FRWT(g)	DRWT(g)	MC %
FIELD	74.5	16	78.2
HIGH TUNNEL	89.6	21	76.2
LSD_(0.05)	NS	NS	NS
GENOTYPE			
CONV	69	16.0	76.7
KPF-4	80.5	17.4	78.9
PURPLE	96.6	23.0	76.1
LSD_(0.05)	10.1	4.23	NS
K-levels(t/ha)			
0	71.8	18.0	75.8
100	92.6	21.3	76.7
200	81.7	17.1	79.2
LSD_(0.05)	14.12	NS	2.6

ENVIR= Environment; FRWT= Fresh weight; DRWT= Dry weight; MC= Moisture content

Table 8 shows the effect of genotype x potassium fertilizer level interactions on the fresh weight, dry weight and moisture content of passion fruit

Interaction of genotype and different potassium rates showed no significant ($P>0.05$) difference on fresh and dry weights except percentage moisture content that varied significantly ($p<0.05$) across the genotypes and fertilizer rates (Table 8). The hybrid KPF-4 genotype that received 200kg/ha potassium fertilizer contained more moisture with mean value of 82.9% than purple variety that received no potassium fertilizer with mean value of 73.3%. Fresh and dry weights were highest on purple genotype with 100kg/ha of potassium fertilizer.

Table 9 shows the Effect of environment x k-levels interactions on the fresh weight, dry weight and moisture content of the three genotypes of passion fruit

Table 9 shows the combined effect of environment and potassium fertilizer interactions. The table revealed that both were statistically similar on fresh and dry weights as well as on the percentage moisture composition. Plants under the high tunnel with 200kg/ha potassium fertilizer produced highest fresh and dry weights while those in the field that received 200kg/ha contained more moisture than plants inside the tunnel without fertilizer with lesser percentage of water.

Table 10 shows the Effect of genotype x environment interactions on the fresh weight, dry weight and moisture content of the three genotypes of passion fruit

Table 10 shows the effect of environment and genotype interactions. This indicated that there was no significant ($P>0.05$) difference on fresh weight, dry weight and moisture content. Purple genotype under the high tunnel was associated with highest fresh and dry weights. Percentage moisture was highest on the hybrid KPF-4 in the field.

Table 8: Effect of genotype x potassium fertilizer level interactions on the fresh weight, dry weight and moisture content of the three genotypes of passion fruit

GENOTYPE	FERTIIZER	FRWT(g)	DRWT(g)	MC(%)
CONV	0	51.5	13.3	75.8
KPF-4	0	81	18.3	78.2
PURPLE	0	83	22.2	73.3
CONV	100	86.5	17.3	79.1
KPF-4	100	87	20.7	75.7
PURPLE	100	104.3	25.8	75.4
CONV	200	69	17.4	75.1
KPF-4	200	73.5	13.1	82.9
PURPLE	200	102.5	20.9	79.5
LSD(0.05)		NS	NS	6.6

FRWT= Fresh weight; DRW= Dry weight; MC= Moisture content

Table 9: Effect of environment x k-levels interactions on the fresh weight, dry weight and moisture content of the three genotypes of passion fruit

ENVIR	FERTIIZER	FRWT(g)	DRWT(g)	MC(%)
FIELD	0	64.9	15.9	76.8
FIELD	100	83.7	19.5	76.7
FIELD	200	74.9	14.4	81.1
HIGH TUNNEL	0	78.8	20	74.7
HIGH TUNNEL	100	101.6	23.1	76.7
HIGH TUNNEL	200	88.4	19.8	77.2
LSD(0.05)		NS	NS	NS

ENVIR= Environment; FRWT= Fresh weight; DRWT= Dry weight; MC= Moisture content

Table10: Effect of genotype x environment interactions on the fresh weight, dry weight and moisture content of the three genotypes of passion fruit

ENVIR	GENOTYPE	FRWT(g)	DRWT(g)	MC(%)
FIELD	CONV	57.9	1.94	78.19
FIELD	KPF-4	75	14.56	81.23
FIELD	PURPLE	90.6	22.31	75.26
HIGH TUNNEL	CONV	80.1	19.04	75.15
HIGH TUNNEL	KPF-4	86.0	20.16	76.61
HIGH TUNNEL	PURPLE	102.7	23.66	76.84
LSD _(0.05)		NS	NS	NS

ENVIR= Environment; FRWT= Fresh weight; DRWT= Dry weight; MC= Moisture content

Table 11 Shows the Main effect of environment, genotype and potassium fertilizer on the biomass of leaf and vine of passion fruit

Environment showed no significant ($p>0.05$) influence on fresh and dry weights of leaf as well as moisture contents of the three genotypes. The highest fresh and dry leaf weight with its moisture content that is 104.6 g, 19.41 g and 80.9% were produced in the field while plants under the high tunnel showed significant ($p<0.05$) increase in fresh and dry vine weights with mean values of 147.4 g and 47.1g, respectively.

Both fresh and dry weights of leaf and vine varied significantly ($p<0.05$) among the three genotypes. The hybrid KPF-4 was associated with highest fresh and dry leaf weights with mean values of 148.1 g, 25.4 g compared to conventional genotype that had least values 75.3 g, 13.8 g of these weights. Fresh and dry vine weights 177.1 g and 55.8 g were also higher on the same genotype while purple genotype showed lesser weights with mean values of 63.3 g and 18.6 g.

Furthermore, percentage moisture content of leaf and vine were statistically similar although conventional genotype contained more water in the leaf with mean value of 80.7% than in the purple while that of vine was highest in purple genotype with mean value of 71.2% than in conventional.

Different rates of potassium fertilizer applied showed no significant ($p> 0.05$) difference on the biomass of leaf and vine of the three genotypes. 100kg/ha of potassium fertilizer increased plant dry leaf weight of 20.08 g (Table 11). Highest fresh leaf weights with its corresponding moisture were observed in plants that received 200kg/ha while those with no potassium fertilizer produced least values. Plants that did not receive any fertilizer had highest fresh and dry vine weights with mean values of 119.1g and 37.9 g compared to those with 20kg/ha that gave lowest values. Percentage moisture was higher in plants with 100kg/ha than in those without fertilizer.

Table 11: Main effects of environment, genotype and k-levels on the leaf and vine of the three passion fruit

Treatments	FRLWT(g)	DRLWT(g)	MC(%)	FRVWT(g)	DRVWT(g)	MC(%)
HighTunnel	100	17.61	79.5	147.4	47.1	67.5
Field	104.6	19.41	80.9	77.6	24.3	69
LSD_(0.05)	NS	NS	NS	14.82	20.26	NS
Genotype						
Conv.	75.3	13.81	80.7	97.1	32.7	66.4
KPF-4	148.1	25.42	80.2	177.1	55.8	67.1
Purple	83.5	16.29	79.8	63.3	18.6	71.2
LSD_(0.05)	27.6	6.964	NS	35.33	13.39	NS
K-levels						
0	79.3	17.02	76.9	119.1	37.9	67
100	106.4	20.08	80.4	113.1	34.7	69.2
200	121.2	18.42	83.4	105.2	34.4	68.5
LSD_(0.05)	NS	NS	NS	NS	NS	NS

FRLWT= Fresh leave weight; DRLWT= Dry leaf weight; FRVWT= Fresh vine weight; DRVWT= Dry vine weight; MC= Moisture content

Table 12 shows the biomass of leaf and vine of passion fruit as influenced by environment and genotype interactions.

There was variation on combined effects of environment and three genotypes on fresh and dry vine weights together with fresh leaf weight. The hybrid KPF-4 under the high tunnel produced significant ($p < 0.05$) higher fresh leaf weight 166.8 g than the conventional genotype under the same environment (Table 12).

Although percentage moisture contents of both leaf and vine were statistically similar, highest leaf moisture was observed on the conventional in the field with mean value of 82.9% and lowest on the same genotype kept inside the high tunnel with mean value of 78.4%. Fresh and dry vine weights were significantly higher on the hybrid under the high tunnel with mean values of 248.8 g and 77.6 g compared to purple genotype in the field that gave lesser values of 46.3 g and 12.3 g, respectively.

However, purple genotype in the field was associated with highest percentage vine moisture 73.5% while the conventional inside the high tunnel gave the least value of 65.7%.

Table 12: Effects of Environment and genotype interaction on the leaf and vine weights of the three passion fruit

Environment	Genotype	FRLWT (g)	DRLWT (g)	MC (%)	FRVWT (g)	DRVWT(g)	MC (%)
High Tunnel	Conv.	55.5	11.4	78.4	113.1	38.5	65.7
High Tunnel	KPF-4	166.8	26.5	80.5	248.8	77.6	67.9
High Tunnel	Purple	77.5	14.9	79.7	80.4	25	68.9
Field	Conv.	95	16.2	82.9	81.1	26.8	67.1
Field	KPF-4	129.4	24.4	79.9	105.3	33.9	66.3
Field	Purple	89.4	17.7	80	46.3	12.3	73.5
	LSD_(0.05)	31.6	NS	NS	40.72	15.33	NS

FRLWT= Fresh leave weight; DRLWT= Dry leaf weight; FRVWT= Fresh vine weight; DRVWT= Dry vine weight; MC= Moisture content

Table 13 shows the interaction effect of environment and potassium fertilizer rates on fresh and dry leaf to vine weights of three genotypes of passion fruit

Fresh leaf weight, fresh and dry vine weights with their moisture contents were not significantly ($p>0.05$) different between the environment and varying rates of potassium fertilizer applied. However, dry leaf weight significantly differed between the environment and fertilizer interactions. Plants that received 100kg/ha of potassium fertilizer under the high tunnel had highest dry leaf weight as well as fresh and dry vine weight with their corresponding mean values of 24.9 g, 163.5 g and 51.3% (Table 13). The lowest weights of these parameters were seen in plants under the high tunnel with no fertilizer and those in the field that received 100kg/ha with mean values of 11.4 g , 62.8 g and 18.1g, respectively.

Meanwhile, environment, genotypes and different potassium fertilizer levels interactions did not influence leaf and vine dry matter partitioning with their respective moisture contents. Highest Fresh leaf weight and percentage leaf moisture were related to KPF-4 genotype under the high tunnel that received 200kg/ha of potassium fertilizer 199.2 g and 87% while lowest value of fresh leaf weight 26.6 g and moisture 71.1% were observed on conventional under the high tunnel and KPF-4 in the field both without fertilizer application.

Fresh and dry vine weights as well as dry leaf weights were statistically similar among genotypes and potassium fertilizer rates in respect to two environments (Table 14). The hybrid KPF-4 under the high tunnel produced highest values of these weights 284.6 g, 82.4 g, and 39.3 g while vine moisture content was highest on purple genotype with no fertilizer in the field.

Table 13: Interaction effects of environment and potassium fertilizer levels on the leaf and vine of three genotypes of passion fruit

Environment	K-level (t/ha)	FRLWT(g)	DRLWT(g)	MC(%)	FRVWT(g)	DRVWT(g)	MC(%)
High Tunnel	0	58.7	11.4	77	149.7	46.2	67.8
High Tunnel	100	125.5	24.9	78.6	163.5	51.3	66.9
High Tunnel	200	115.7	16.5	82.9	129	43.6	67.8
Field	0	99.9	22.6	76.8	88.6	29.6	66.1
Field	100	87.3	15.2	82.2	62.8	18.1	71.6
Field	200	126.7	20.4	83.8	81.3	25.2	69.2
LSD _(0.05)		NS	6.8	NS	NS	NS	NS

FRLWT= Fresh leave weight; DRLWT= Dry leaf weight; FRVWT= Fresh vine weight;
DRVWT= Dry vine weight; MC= Moisture content

Table 14 Effects of environment x genotype x potassium fertilizer on the leaf and vine of the three genotypes of passion fruit

Environment	Genotype	K-level (t/ha)	FRLWT (g)	DRLWT (g)	MC (%)	FRVWT (g)	DRVWT (g)	MC (%)
High Tunnel	Conv	0	26.6	6.35	75.4	110.7	37.1	66.5
High Tunnel	Conv	100	61.4	13.4	78.5	104.5	39.2	62.5
High Tunnel	Conv	200	78.6	14.55	81.4	124	39.2	68.2
High Tunnel	KPF-4	0	112.2	18.75	79.6	271.4	79.7	70.1
High Tunnel	KPF-4	100	189.1	39.3	74.8	284.6	82.4	70.1
High Tunnel	KPF-4	200	199.2	21.3	87	190.2	70.8	63.4
High Tunnel	Purple	0	37.3	9.05	76.1	66.8	21.9	66.9
High Tunnel	Purple	100	126.1	22.15	82.4	101.4	32.3	68.1
High Tunnel	Purple	200	69.1	13.6	80.5	72.8	20.7	71.6
Field	Conv	0	86.4	15.75	81.8	86.2	26.3	69.3
Field	Conv	100	97.7	16.35	83.4	81.2	24.9	69.3
Field	Conv	200	101	16.45	83.6	76	29.1	62.6
Field	KPF-4	0	122.8	32.05	71.1	133	50.4	54.9
Field	KPF-4	100	111.8	19.1	82.8	73.2	20.4	72.1
Field	KPF-4	200	153.6	22	85.8	109.8	30.8	72.1
Field	Purple	0	90.4	20.15	77.6	46.7	12.1	74.2
Field	Purple	100	52.2	10.2	80.5	33.9	9	73.3
Field	Purple	200	125.6	22.6	82	58.1	15.7	72.8
LSD _(0.05)			NS	NS	NS	NS	NS	13.49

FRLWT= Fresh leave weight; DRLWT= Dry leaf weight; FRVWT= Fresh vine weight;
DRVWT= Dry vine weight; Mc= Moisture content

Table 15: Fruit matrix traits as influenced by genotype and potassium fertilizer

The combined effects of genotype and potassium levels on fruit matrix revealed that the conventional genotype with 100kg/ha produced more percentage juice weight, seed weight and juice volume compared with the hybrid with no fertilizer that had the least of these values. Percentage pulp weight was highest on the hybrid that did not receive fertilizer.

Table 16: Effects of genotype, k-levels and their combination on fruit yield and yield component of passion fruit

There is a significant difference in fruit yield and yield components between the genotypes (Table 16). The conventional genotype produced more and heavier fruits 6.1 and 401 g than the hybrid KPF-4. Longer, wider and thicker fruits were significantly produced by the hybrid KPF-4 than the conventional genotype.

Application of potassium fertilizer significantly influenced fruit yield and its components (Table 16). Higher number of fruits 6.9, heavier and wider fruits 478g and 6.7cm with thick pulp 4.7mm were produced when 200kg/ha potassium fertilizer was applied compared to those with no fertilizer that gave lesser values of 2.9, 201g, 5.5cm and 2.6mm, respectively. Genotype and potassium fertilizer interactions did not vary significantly on fruit yield and yield components. Nevertheless, fruit length and circumference were higher on the hybrid that received 200kg/ha (Table 16). The same genotype with 100kg/ha had higher rind thickness than the conventional which produced more fruit than the hybrid.

Table 15: Fruit matrix traits as influenced by genotype, K- levels

GENOTYPE	k-level t/ha	FRT NO	FRTWT (g)	SEDWGT (g)	JUCEWGT (g)	JUCEVOL (ml)
CONV	0	9	702.6	92.5	159.9	173
CONV	100	9	700.3	116.3	211.6	218
CONV	200	9	664.4	60.5	175.9	181
KPF 4	0	9	441.2	27.5	50.6	62
KPF 4	100	9	672.5	60.3	140.5	130
KPF 4	200	9	485.9	55.8	113.8	120

FRT= fruit number; FRTWT= Fruit weight; SEDWT= Seed weight, JUCEWGT=Juice weight;
JUICE VOL= Juice Volume

Table15

GENOTYP E	K- LEVELS	FRTWT(g)	SEEDWT %	JUICEWT %	JUICVOL(m l)	PULPWT %
CONV	0	702.6	13.2	22.8	173	60.6
CONV	100	700.3	16.6	30.1	218	56.7
CONV	200	664.4	9.1	26.5	181	64.4
KPF 4	0	441.2	6.2	11.5	62	82.3
KPF 4	100	672.5	9.0	20.9	130	70.1
KPF 4	200	485.9	11.5	23.4	120	65.1

Table 16: Effects of genotype, k-levels and their combination on fruit yield and yield components of passion fruit

GENOTYPE	FRUIT NO	FRUIT DIA(cm)	FRT LENTH(cm)	RIND THIK (mm)	FRT WT (g)
CONVENTIONAL	6.1	5.5	9.1	3.3	401
KPF-4	4.8	5.9	10.1	4.8	333
LSD_(0.05)	NS	NS	0.973	1.39	NS
K-LEVELS					
0	2.9	5.5	10.4	2.6	201
100	6	5.1	9	4.8	423
200	6.9	6.7	9.3	4.7	478
LSD_(0.05)	3.2	NS	1.2	1.7	233.3
GENOTYPE	K-LEVEL(t/ha	FRT NO	FRTDIAM(cm)	FRTLENGHT(cm)	RIND THK(mm)
CONVENTIONAL	0	3.4	4.5	10.4	1.8
KPF-4	0	2.4	6.5	10.5	3.4
CONVENTIONAL	100	7.6	5.7	8.9	3.5
KPF-4	100	4.4	4.4	9.2	6.1
CONVENTIONAL	200	7.3	6.5	8	4.5
KPF-4	200	6.6	6.8	10.5	5
	LSD_(0.05)	NS	NS	NS	NS
FRTDIAM = Fruit diameter (cm), FRT LT = Fruit length (cm), RMDTHK = Rindthickness (mm), FRT WT = Fruit weight (g)					

Table 17: Effect of genotypes, k- levels and their interactions on fruit weight loss of two genotypes of passion fruit

Table 17 revealed that initial weight of the fruits varied significantly between the two genotypes, conventional genotype weighed higher (78.0 g) than the hybrid before storage. Subsequent percentage weight loss was statistically similar between the both genotypes. However, the hybrid KPF-4 lost more water than the conventional genotype.

Different potassium fertilizer levels applied significantly ($p < 0.05$) influenced percentage weight loss. Higher percentage of fruit weights loss were observed on KPF-4 and conventional genotypes with 0kg/ha followed by those with 200kg/ha. Decrease in weight loss was observed in plants that received 100kg/ha. Genotype and potassium fertilizer interactions did not show significant difference on weight loss.

Table 17: Effects of genotype, potassium level, and their combination on percentage weight loss of two genotypes of passion fruit.

		DAYS				
GENOTYPE	INITALWT	3	6	9	12	
CONVENTIONAL	78	13.6	31.1	45.5	57.5	
KPF-4	66.7	18.1	38.7	51.7	56.7	
LSD(0.05)	8.85	NS	NS	NS	NS	
K-LEVELS						
0	40.6	26.4	50.1	64.3	74.4	
100	85.3	11.2	23.1	36.5	48.2	
200	91.2	10	31.7	45.2	56.7	
LSD(0.05)	10.84	5.82	NS	9.49	6.48	
GENOTYPE	K-LEVELS	INITIALWEIGHT	3	6	9	12
CONVENTIONAL	0	43.6	22.9	45.4	61.3	73.2
CONVENTIONAL	100	102.8	10	18.3	32.1	44.1
CONVENTIONAL	200	87.5	8	29.7	43.2	55.2
KPF-4	0	37.5	29.8	54.7	67.3	75.7
KPF-4	100	67.7	12.4	27.9	40.8	52.3
KPF-4	200	94.8	12.1	33.6	47.1	58.1
LSD(0.05)		15.33	NS	NS	NS	NS
LSD(0.05)		NS	NS	NS	NS	NS

EXPERIMENT 2

Effect of potassium fertilizer rates on biochemical and nutritional quality of two genotypes of passion fruit

Table 18 shows mineral concentration of passion fruit juice as influenced by genotype and different potassium fertilizer levels

Nitrogen and potassium contents of the juice significantly ($P < 0.05$) differed between the two genotypes. Conventional genotype contained more nitrogen and potassium with mean values of 0.097mg/100g and 2080mg/100g than KPF-4 that gave lesser values. Although phosphorous content of both genotypes was statistically similar, highest quantity of it was recorded on conventional variety.

Different potassium fertilizer rates applied significantly increased concentration of potassium mineral in the juice (Table 18). Plants that received 200kg/ha of potassium fertilizer had highest potassium content with mean value of 2173mg/100g while those plants that did not receive potassium fertilizer had the lowest value of 1801mg/100g.

There was no significant difference on the combined effects of genotypes and potassium fertilizer levels on mineral concentrations of passion fruit juice (Table 19). The two genotypes had almost the same nitrogen content but varied slightly in phosphorous and potassium contents. Phosphorous was highest on conventional genotype with no potassium fertilizer 7.19 g/kg whereas the same genotype that received 200kg/ha potassium fertilizer gave the highest concentration 2370mg/100g of potassium mineral.

Table 18: Main effects of genotype and K-levels on the mineral content of passion fruit

GENOTYPES	N(mg/100)	P(g/kg)	K (mg/100)
CONV	0.097	6.38	2080
KPF-4	0.087	4.66	1854
LSD(0.05)	0.010	NS	189.8
K- LEVELS(kg/ha)			
0	0.093	5.9	1801
100	0.092	5.53	1929
200	0.090	5.13	2173
LSD(0.05)	NS	NS	232.4

Table 19: Effect of genotype and K-level interaction on the mineral content of passion fruit

GENOTYPE	K-LEVEL	N(mg/100)	P(g/kg)	K (mg/100)
CONV	0	0.098	7.19	1923
CONV	100	0.096	7.03	1949
CONV	200	0.098	4.93	2370
KPF-4	0	0.098	4.6	1679
KPF-4	100	0.088	4.04	1909
KPF-4	200	0.083	5.33	1975
LSD(0.05)		NS	NS	NS

Effect of genotype and potassium fertilizer levels on the proximate contents of passion fruit

Percentage fruit colour, fat, moisture and hydrogen cyanide concentrations were statistically similar between the two genotypes (Table 20). Conventional variety was associated with more fruit colour, fat and hydrogen cyanide with their corresponding mean values of 4.1%, 0.27%, and 0.009 mg/100, respectively.

However, percentage protein indicated significant ($p < 0.05$) difference in the two genotypes. Higher percentage of protein was recorded on the conventional genotype 0.607% while the hybrid showed lesser value of 0.541%.

Proximate content of the two genotypes did not show significant ($p > 0.05$) difference on varying rates of potassium fertilizer. Plants that received 200kg/ha gave higher percentage fruit colour and moisture content with mean values of 4.1% and 94.2%, respectively. Fat and hydrogen cyanide composition were virtually the same while protein content decreased with increase in fertilizer rates.

Genotype and potassium fertilizer interactions were statistically similar across the proximate compositions except for fat content (Table 21). Percentage fat showed significant ($p < 0.05$) increase in the conventional genotype that received 100kg/ha potassium fertilizer compared to KPF-4 with the same rate of potassium fertilizer.

Conventional genotype had higher percentage fruit colour 4.2% when 200kg/ha potassium fertilizer was applied compared to KPF-4 with 0kg/ha that gave lesser value of 3.8%. Protein content was highest on conventional genotype that received 200kg/ha as well as on those with no potassium fertilizer and lowest in KPF-4 with 200kg/ha potassium fertilizer (Table 21). Percentage fat and hydrogen cyanide were almost the same between the genotypes and among the fertilizer rates.

Table 20: Main effect of genotype and K-levels on the proximate content of the passion fruit

GENOTYPES	COLR (%)	FAT (%)	HCN(mg/100g)	PROTEIN (%)	MOISTRE (%)
CONV	4.1	0.27	0.009	0.607	92.59
KPF-4	4.03	0.24	0.008	0.541	92.72
LSD_(0.05)	NS	NS	NS	0.0621	NS
K-LEVELS(t/ha)					
0	3.97	0.25	0.009	0.583	90.85
100	4.08	0.25	0.009	0.573	92.96
200	4.14	0.25	0.007	0.565	94.16
LSD_(0.05)	NS	NS	NS	NS	NS

Table 21: Effect of genotype and K-levels interaction on the proximate content of passion fruit

GENOTYPE	K-LEVEL (t/ha)	COLR (%)	FAT (%)	HCN (mg/100g)	PROTEIN (%)	MOISTRE (%)
CONV	0	4.1	0.28	0.01	0.61	92.23
CONV	100	4.03	0.29	0.01	0.6	90.9
CONV	200	4.16	0.23	0.01	0.61	94.65
KPF-4	0	3.83	0.22	0.01	0.56	89.48
KPF-4	100	4.12	0.21	0.01	0.55	95.01
KPF-4	200	4.12	0.28	0.01	0.52	93.68
LSD_(0.05)		NS	0.032	NS	NS	NS

Effects of genotype and potassium fertilizer level interaction on the phytochemical content of passion fruit juice

There was no significant ($p>0.05$) difference on oxalate, phenol, phytate and tannin contents of the two genotypes (Table 22). They had almost the same concentrations of these compounds.

However, these compounds were statistically similar among different rates of potassium fertilizer. Oxalate, phytate and tannin were highly produced in plants that received 200kg/ha potassium fertilizer than those with no fertilizer that gave lesser concentrations of these compounds.

The combined effects of genotypes and potassium fertilizer levels did not influence phytochemical content of passion fruit juice (Table 23). The two genotypes had almost the same concentrations of these compounds along the varying fertilizer levels.

Table 22: Main effect of genotype and K-levels on the phyto-chemical content of passion fruit

GENOTYPES	OXALATE (mg/100g)	PHENOL (mg/100g)	PYTATE (mg/100g)	TANIN (mg/100g)
CONV	0.013	0.004	0.021	0.0023
KPF-4	0.013	0.004	0.021	0.0023
LSD_(0.05)	NS	NS	NS	NS
K- LEVELS(t/ha)				
0	0.0127	0.0039	0.021	0.0023
100	0.0128	0.0041	0.022	0.0023
200	0.0130	0.0041	0.030	0.0024
LSD_(0.05)	NS	NS	NS	NS

Table 23: Effect of genotype and K-levels interaction on the phyto-chemical content of passion fruit

GENOTYPE	K- LEVELt/ha	OXALATE			
		(mg/100g)	PHENOL (mg/100g)	PYTATE (mg/100g)	TANIN (mg/100g)
CONV	0	0.013	0.0037	0.022	0.0023
CONV	100	0.013	0.004	0.022	0.0023
CONV	200	0.013	0.004	0.021	0.0023
KPF-4	0	0.012	0.004	0.021	0.0022
KPF-4	100	0.012	0.004	0.021	0.0022
KPF-4	200	0.013	0.004	0.021	0.0023
LSD_(0.05)		NS	NS	NS	NS

Main effect of genotype and potassium fertilizer on Ph, total soluble solid, total titratable acidity, vitamin C of passion fruit juice.

The two genotypes were significantly ($p < 0.05$) different on the pH and vitamin C content of the juice (Table 24). The conventional genotype showed highest concentration of vitamin C and pH with mean values of 24.4 and 3.2 while KPF-4 gave the least values of 23.9 and 3.1 respectively. Total titratable acidity, reducing sugar and solubility solid were statistically similar between the two genotypes

Application of different levels of potassium fertilizer did not show variation on the phyto – chemical contents of the two genotypes. Meanwhile, sugar content and soluble solid were higher in plants that received 200kg/ha followed by those with no fertilizer. However, interactions of genotype and potassium rates showed no significant different for the phyto chemicals (Table 25).

Table 24: Main effect of genotype and K-levels on the phyto-chemical content of the passion fruit

GENOTYPES	RS%	SS%	TTA%	VAGL	VC	PH
CONV	8.80	15.91	0.26	131.6	24.4	3.16
KPF-4	8.79	15.87	0.26	134.4	23.9	3.04
LSD_(0.05)	NS	NS	NS	NS	0.4	0.13
K- LEVELS (kg/ha)						
0	8.8	15.9	0.273	135.1	24.1	3.1
100	8.7	15.7	0.255	129.7	24.1	3.2
200	8.9	16.0	0.245	134	24.2	3.1
LSD_(0.05)	NS	NS	NS	NS	NS	NS

Table 25: Effect of genotype and K-levels interaction on the phyto-chemical content of the passion fruit

GENOTYPE	K- LEVEL	RS%	SS%	TTA%	VAGL	VC	PH
CONV	0	8.8	15.93	0.25	138.5	24.2	3.15
CONV	100	8.88	15.96	0.27	125.1	24.37	3.14
CONV	200	8.73	15.85	0.26	131.2	24.6	3.2
KPF-4	0	8.74	15.87	0.29	131.8	24.07	2.97
KPF-4	100	8.58	15.53	0.24	134.4	23.89	3.21
KPF-4	200	9.05	16.2	0.23	137	23.61	2.94
LSD_(0.05)		NS	NS	NS	NS	NS	NS

DISCUSSION

GROWTH RESPONSES OF THREE GENOTYPES OF PASSION FRUIT AS INFLUENCED BY ENVIRONMENT

The significant differences in number of unifoliate leaves at varying months among the three genotypes; purple, KPF-4 and conventional under high tunnel as well as in the field could be attributed to differences in the genetic constitution of the three genotypes that regulated leaf formation and development. Brian *et al.*, (1954) reported that particularly in the later stages of leaf development, hormonal substances with similar effect on the gibberellins may play an important role in governing the course of leaf development. Number of bifoliate and trifoliate leaves did not show any significant difference between the two environments but were consistently higher in plants under the high tunnel than those in the field. This might be due to changes in environmental conditions (temperature and light intensity) inside the tunnel because light influences many phases of plant growth and development. Low light intensity promotes elongation of the leaf petiole while inhibiting expansion of the leaf blade. This agrees with Tsukaya (2005) report that effects of light intensity on leaf shape can involve both cell expansion and cell replication.

However, significant increase in vine lengths of plants inside the tunnel suggested that it provided optimum growing environmental conditions that favoured vegetative growth of plant. This agrees with Carey *et al.* (2009); Lamont (2009) reports that protecting crops under plastic (polyethylene), either with high tunnels or greenhouses generates changes in the environmental conditions of light, temperature and relative humidity that may have effects on the productive and physiological responses of the plant.

The results of the current work revealed that plants fresh biomass did not vary between the high tunnel and open field though they developed different fresh and dry weights which were higher in plants inside the tunnel. This could probably be that better growing conditions

provided to the plants enabled them to absorb greater quantity of nutrients from the soil than those in the field. Meanwhile, plants in both environments showed similarity in fresh and dry leaf weights but significantly differed in their fresh vine weights. This implied that plants inside the high tunnel might have already absorbed nutrients more easily and in greater amounts than those in the field. The assumed differences in nutrient absorption among plants in both environments resulted to differences in dry matter accumulation in the vine which was higher in plants under the tunnel. The significant response of morphological growth parameters (number of unifoliate, bifoliate and trifoliate leaves, number of branches and vine length) observed on three genotypes of passion fruit seedlings assumed differences in their genetic makeup and tolerance to environmental conditions. The hybrid KPF-4 produced higher number of unifoliate and bifoliate leaves, had the longest vine 260.6 cm and highest number of branches 13.1 than other genotypes. This progressive increase in number of branches and vine length in the hybrid may be attributed to its better adaptation to the experimental site and higher absorption of nutrients and water from the soil, thus more nutrients were translocated to the upper parts of plants which grew longer than that of the conventional genotype. This is in line with Kareem (2013) report on sweet potatoes that medium sized vine length ranged from 140-180 cm gave the best yield of sweet potato.

The significant differences observed in fresh biomass and dry matter weights among the genotypes indicated that purple genotype may have accumulated more nutrients than others. Also variations in fresh and dry leaf weights and dry matter partitioning to the leaf and vine among the three genotypes suggested that the hybrid KPF-4 had higher nutrients absorption and translocation to the upper parts of plants that had led to the production of a higher number of leaves and greater leaf biomass. It is well noted that Leaves are the major organs that trap photosynthetically active radiation (PAR) to produce carbohydrates needed to build new vegetative and reproductive structures. This proposed that greater number of leaves

produced by the hybrid must have promoted a higher biomass allocation and consequently a higher dry matter content in leaves. According to Lizarazo *et al.*, (2013) approximately 90% of accumulated dry matter during plant growth is the product of photosynthetic activity while the remaining percentage comes from mineral absorption

Growth response of three genotypes of passion fruit seedlings to potassium fertilizer levels

The result of the study revealed that unifoliate and bifoliate leaves, number of branches and vine length were statistically similar except number of trifoliate leaves that showed significant increase at some months when 200kg/ha was applied. Nevertheless, greater number of these growth parameters were observed in plants that received 200kg/ha and 100kg/ha than those without fertilizer application. This could mean that certain growth parameters require specific potassium rate for their growth and Prado *et al.*, (2004) had similar results on evaluation of different potassium doses on yellow passion fruit seedlings, which showed that plants attained maximum height with a dose of 220mg/dm³ of potassium fertilizer.

Mello (2016) reported that passion fruit requires potassium throughout its growing season and the amount of this nutrient varies at their various stages of growth.

The interactions of high tunnel and fertilizer rates on all vegetative growth parameters were found to be statistically similar across the months except number of trifoliate leaves that showed significant difference at two months. Plants under the high tunnel that received 100 kg/ha of potassium fertilizer produced longer vine length and higher number of trifoliate leaves than those in the field with no fertilizer. Presence of greater number of trifoliate leaves in passion fruit is an indication that it is moving from vegetative stage to reproductive stage, thus this showed that combined effects of potassium fertilizer and high tunnel produced highly vigorous plants. Potassium had been reported by Mikklesen (2008) as the soil cation

required in largest amount by plants to maintain healthy growth and vigour regardless of nutrient management philosophy.

Significant and non significant effects of genotypes and environments on growth parameters across the varying months indicated that the hybrid KPF-4 performed better both inside the tunnel and in the open field than other two genotypes, probably due to their genetic variations and its ability to tolerate varying environmental conditions. Chalaich and Kulkarni (1977) reported that the yield of potato was higher when polyethylene mulch was used. Increasing rates of potassium fertilizer among the three genotypes were found to be significant on vine length at two and three months and non significant in other growth parameters. KPF-4 genotype that received 200kg/ha produced higher number of bifoliate and trifoliate leaves, longer vines and contained more moisture while conventional and purple genotypes with 100kg/ha produced higher number of branches and dry matter composition. This variability in potassium uptake in genotypes of passion fruits may be attributed to their differences in genetic constitution and other environmental factors. This corroborates with Rengel et al. (2008) report that potassium uptake in plants depends on genetic differences and developmental stages of the plant including both the vegetative versus reproductive stages. Lester and Rogers (2005) also noted that in many fruit species, uptake of potassium occurs mainly during vegetative stages when greater quantity of carbohydrate is available for root growth. Hussein *et al.* (2008) showed that K_2PO_3 foliar fertilization positively affected parameters of cowpea grown under salinity stress conditions such as plant heights, number of green leaves per plant and both fresh and dry weights. There was variation on combined effects of environment and three genotypes of passion fruit on dry matter partitioning to the above ground components. The hybrid KPF-4 under the high tunnel showed significant increase in fresh leaf weight, fresh vine weight and dry matter partitioning than conventional and purple genotype. This could mean that the hybrid had a higher level of adaptation to the

soil and climatic conditions of the experimental site compared to the level of adaptation of plants of other genotypes. This better adaptation resulted into development of stronger root system, higher plant height and consequently a higher number of leaves for higher photosynthetic activity and higher biomass accumulation to the leaves and vines.

However, the responses of fresh weight and dry weight as well as dry matter partitioning to the above ground components of the three genotypes on environment and fertilizer interactions indicated similarity although plants under the high tunnel that received 100kg/ha of potassium fertilizer had highest dry leaf weight. The increase in leaf and vine dry matter may be due to application of potassium fertilizer that increased rate of photosynthesis and nutrient absorption.

The combined effects of environment, genotypes and potassium fertilizer levels interactions did not influence leaf and vine dry matter partitioning. Fresh and dry vine weights together with dry leaf weights were statistically similar among the genotypes and potassium fertilizer rates with respect to environments. The hybrid KPF-4 under the high tunnel with 200kg/ha performed better than other genotypes.

Genotype and potassium fertilizer influence on biochemical qualities of two genotypes of passion fruits

The significant differences in nitrogen and potassium mineral concentrations obtained in the juice of the two genotypes could be attributed to their differences in nutrient absorption. Conventional genotype contained more concentrations of these minerals than the hybrid KPF-4. However, their concentrations fell within the recommended dietary doses needed for human consumption. According to National Academy of Sciences (2001 and 2005) daily intake for P ranges from 460 to 700 mg/day and that of K is 348mg.

Application of potassium fertilizer significantly increased concentration of potassium in the fruit juice probably because of its active involvement in nutrient absorption. Nitrogen and phosphorous minerals showed similarity in their composition this could mean that potassium fertilizer helps to maintain a balance in the amount of nutrient absorbed by plants. Joy (2010) noted that from the start of fruit formation there is a great demand for energy by the plant and a strong translocation of nutrients from the leaves to the developing fruits. Plants with higher dose of potassium fertilizer had higher concentration of these minerals than those with no fertilizer. This may be due to active involvement of potassium in the activation of enzymes and production of energy that aids in transport of water and nutrients in plant. This agrees with Pettigrew (2008) report that potassium is also involved in active transportation of nutrients and photoassimilates through the xylem and phloem to sink and source tissues. Haag *et al.* (1973) also reported that macro nutrients are taken up in greater quantities by passion fruit and of all the nutrients removed in the harvested fruits by far the largest quantity is potassium followed by nitrogen.

Although percentage fruit colour, fat, moisture and hydrogen cyanide concentrations did not vary between the two genotypes, conventional variety produced fruits that were more colourful with higher fat content. The variation observed for percentage protein indicated that both genotypes differ in their genetic expressions. The significant and non significant effect of genotype and potassium fertilizer interactions on percentage fat, fruit colour, protein and moisture revealed that increase in fertilizer increased production of these phytochemicals in the two genotypes. Xiang *et al.* (2013) reported that application of potassium fertilizer improves mechanical and biochemical composition of soyabeans.

There was no significant differences on oxalate, phenol, phytate and tannin contents of the two genotypes. They had almost the same concentration of these compounds probably because they are genetically related.

However, these compounds were statistically similar among different rates of potassium fertilizer. The combined effect of genotypes and potassium fertilizer levels did not influence phyto- chemical content of passion fruit juice; the two genotypes had almost the same concentrations of these compounds along the varying fertilizer levels. Generally their concentrations were low such that it can be freely consumed without any harmful effect on the body.

Effects of genotype and potassium fertilizer on PH, total soluble solid, total titratable acidity, moisture and vitamin C of passion fruit juice.

The pH values and vitamin C content of the juice of the two genotypes varied significantly. The conventional genotype showed highest concentration of vitamin C and pH while KPF-4 gave the least values. Total titratable acidity, reducing sugar and soluble solid and moisture were statistically similar between the two genotypes. However, higher juice moisture contents of both genotypes (92.59% and 92.72%) compared with Ogbonna *et al.* (2013) findings in juice moisture content in orange (85.85%) pineapple (83.99%) and pawpaw (82.74%) present them as a good source of hydration for body. Total titratable acidity decreased at higher potassium application compared to Kondo and Higuchi (2013) report findings that total acidity decreases at lower potassium application rate. This implied that potassium helps to reduce acid content of the passion fruit juice. The values reported in this current work for total soluble solid was in agreement with results found earlier by Silvia *et al* (2015). He reported that during maturation of passion fruits, there is an increased in amount of TSS with values ranging from 10.2⁰ Brix to 16.8⁰Brix.

Genotype and potassium fertilizer interactions were statistically similar across the proximate composition except on fat content. Percentage fat showed significant increase with conventional genotype that received 100kg/ha potassium fertilizer compared to KPF-4 with

the same quantity of fertilizer. Conventional had higher percentage fruit colour 4.2% when 200kg/ha potassium fertilizer was applied.

Effects of genotype and potassium fertilizer on fruit yield, quality, yield component and post harvest quality of passion fruit

The yield differences observed between the genotypes indicated that conventional genotype produced more and heavier fruits than the hybrid, while longer, wider and thicker fruits were significantly produced by the hybrid KPF-4. Application of potassium fertilizer significantly influenced fruit yield and its components. Higher number of fruits, heavier and wider fruits with thick pulp were produced when 200kg/ha potassium fertilizer was applied than those with no fertilizer. This could be accounted for its regulatory role in improving quality of fruit. This corroborates with Mehdi *et al.* (2007); Zekri and Obreza, (2009); Hawkesford *et al.* (2012) report findings that potassium improves synthesis of protein, carbohydrates, fats and translocation of photosynthates from the leaves to the fruits. Borges *et al.* (1998) also noted that increase in length and diameter of the fruit was observed with the application of larger amounts of potassium. These results also agree with the report of Ndukwe (2018) that conventional genotype out yielded the hybrid but the fruit matrix traits of the hybrid were better. It has been studied that potassium in its deficiency reduces the weight of the plant and the production of fruits which fall prematurely or shrivel Manica, (1981). Percentage weight loss was statistically similar between the two genotypes. However, the hybrid KPF-4 lost more water than the conventional genotype.

Different potassium fertilizer levels applied significantly influenced percentage weight loss. Plants with no fertilizer lost more weight which was consistent across the days followed by those with 200kg/ha. Decrease in weight loss was observed in plants that received 100kg/ha. Genotype and potassium fertilizer interactions did not show significant difference on weight loss.

Higher percentage fruit weights loss were observed on KPF-4 and conventional genotypes with 0kg/ha followed by those with 200kg/ha. Both genotypes that received 100kg/ha had lesser percentage weight loss. Kumar and Kavino, (2006) reported that potassium appears to have profound influence on improving quality of the fruits by maintaining desirable sugar to acid ratio; it affects fruit size, appearance, colour, vitamin contents and ripening of fruit.

CONCLUSION

Purple genotype cannot adapt favourably in Nsukka zone because it grows best at a higher altitudes above 2000m in the tropic.

The study revealed that the hybrid genotype can adapt favourably in Nsukka region than the conventional since most of its growth and yield parameter did not vary significantly with the conventional.

High tunnel favours only vegetative growth of passion fruits, its flowering and fruiting require an environment where day length is greater than eleven hours since it is a long day plant.

Application of potassium fertilizer greatly influenced growth, yield and post harvest quality of passion fruit. 100kg/ha is the recommended dose based on the limited current study.

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APPENDIX

Effects of environment X genotype X fertilizer interaction on growth parameters of passion fruit at different months after treatment application

1MAT							
ENVIR	GENOTYPE	FERTIIZER	UNIFL	BIFL	TRFL	BRCH	VINL
FIELD	CONV	0	32.7	1.0	4.7	2.0	131.7
FIELD	KPF-4	0	48.0	1.3	1.7	2.7	114.3
FIELD	PURPLE	0	31.7	4.3	10.7	4.3	65.3
HIGH							
TUNNEL	CONV	0	19.3	1.0	10.3	2.3	140.3
HIGH							
TUNNEL	KPF-4	0	36.0	1.3	3.0	3.0	139.0
HIGH							
TUNNEL	PURPLE	0	16.7	1.7	19.0	2.7	92.0
FIELD	CONV	100	38.3	3.0	5.3	2.0	110.3
FIELD	KPF-4	100	46.0	2.3	5.7	2.7	126.7
FIELD	PURPLE	100	21.3	3.3	23.7	3.3	82.7
HIGH							
TUNNEL	CONV	100	25.0	1.7	8.0	2.0	145.0
HIGH							
TUNNEL	KPF-4	100	30.0	3.3	3.0	2.3	138.7
HIGH							
TUNNEL	PURPLE	100	24.0	2.3	23.0	3.7	99.7
FIELD	CONV	200	36.0	2.0	10.7	3.0	113.7
FIELD	KPF-4	200	50.0	3.0	2.0	3.0	124.7
FIELD	PURPLE	200	29.7	3.7	23.7	4.3	81.7
HIGH							
TUNNEL	CONV	200	27.3	2.3	8.3	2.3	138.3
HIGH							
TUNNEL	KPF-4	200	34.0	0.7	5.7	2.3	147.3
HIGH							
TUNNEL	PURPLE	200	15.0	2.0	21.0	3.0	91.3
LSD _(0.05)			NS	NS	NS	NS	NS
2MAT							
FIELD	CONV	0	43.2	1.0	3.0	3.3	112.7
FIELD	KPF-4	0	52.3	0.7	3.3	4.0	112.3
FIELD	PURPLE	0	36.3	4.3	16.7	5.3	71.0
HIGH							
TUNNEL	CONV	0	18.3	1.3	21.3	2.3	203.0
HIGH							
TUNNEL	KPF-4	0	43.3	4.3	10.0	4.0	172.0
HIGH							
TUNNEL	PURPLE	0	15.3	2.0	33.7	3.3	123.7
FIELD	CONV	100	49.3	2.7	7.7	4.0	115.0

FIELD	KPF-4	100	55.3	2.3	2.0	3.3	129.7
FIELD	PURPLE	100	29.0	4.3	33.0	4.3	87.3
HIGH							
TUNNEL	CONV	100	31.7	3.7	17.3	3.0	185.0
HIGH							
TUNNEL	KPF-4	100	38.0	4.7	8.7	3.0	186.0
HIGH							
TUNNEL	PURPLE	100	22.0	2.3	43.7	4.7	140.0
FIELD	CONV	200	32.7	1.7	17.0	3.7	121.7
FIELD	KPF-4	200	55.3	3.3	7.0	3.7	125.0
FIELD	PURPLE	200	27.0	4.3	38.7	4.3	76.0
HIGH							
TUNNEL	CONV	200	31.7	3.0	18.0	3.0	160.0
HIGH							
TUNNEL	KPF-4	200	40.0	4.0	16.3	3.7	209.3
HIGH							
TUNNEL	PURPLE	200	17.0	2.3	32.3	3.3	132.3
LSD _(0.05)			NS	NS	NS	NS	22.9

ENVIR	GENOTYPE	FERTIIZER	UNIFL	BIFL	TRFL	BRCH	VINL
3MAT							
FIELD	CONV	0	21.3	1.7	5.7	2.0	131.3
FIELD	KPF-4	0	20.3	1.7	4.0	1.7	120.7
FIELD	PURPLE	0	10.0	5.3	13.3	0.7	65.0
HIGH							
TUNNEL	CONV	0	9.0	1.0	25.0	2.7	268.7
HIGH							
TUNNEL	KPF-4	0	26.0	2.7	14.7	4.7	198.7
HIGH							
TUNNEL	PURPLE	0	3.7	2.0	25.3	1.7	185.3
FIELD	CONV	100	18.3	1.7	5.7	0.7	123.0
FIELD	KPF-4	100	15.0	1.7	2.0	1.7	105.7
FIELD	PURPLE	100	7.3	1.3	21.3	2.0	81.0
HIGH							
TUNNEL	CONV	100	13.7	2.0	20.7	2.3	227.0
HIGH							
TUNNEL	KPF-4	100	25.3	4.7	15.7	3.3	243.3
HIGH							
TUNNEL	PURPLE	100	2.3	0.7	33.0	1.3	201.7
FIELD	CONV	200	10.0	1.7	16.0	2.0	123.0
FIELD	KPF-4	200	23.0	9.3	11.3	2.3	140.0
FIELD	PURPLE	200	3.0	1.3	22.7	2.3	73.0
HIGH							
TUNNEL	CONV	200	9.7	4.3	21.3	2.3	243.3
HIGH							
TUNNEL	KPF-4	200	23.0	5.7	21.7	5.0	234.0
HIGH							
TUNNEL	PURPLE	200	1.7	1.7	21.3	2.0	146.3
LSD _(0.05)			NS	NS	NS	NS	NS
4MAT							
FIELD	CONV	0	52.3	11.7	12.0	5.0	150.3
FIELD	KPF-4	0	56.0	5.0	6.3	5.0	140.3
FIELD	PURPLE	0	6.0	2.7	26.0	2.0	88.7
HIGH							
TUNNEL	CONV	0	12.0	5.3	50.7	5.0	276.0
HIGH							
TUNNEL	KPF-4	0	69.0	11.7	27.7	7.0	240.0
HIGH							
TUNNEL	PURPLE	0	2.7	1.0	31.3	2.7	241.0
FIELD	CONV	100	37.3	5.3	20.0	4.0	141.3
FIELD	KPF-4	100	49.7	2.7	2.0	4.0	124.7
FIELD	PURPLE	100	3.7	1.7	40.7	3.0	99.0
HIGH							
TUNNEL	CONV	100	16.3	3.7	41.7	5.0	199.0

HIGH TUNNEL	KPF-4	100	50.3	10.0	37.0	7.3	294.3
HIGH TUNNEL	PURPLE	100	2.0	0.3	60.3	4.3	251.0
FIELD	CONV	200	17.3	4.7	26.7	3.3	135.3
FIELD	KPF-4	200	48.3	6.0	24.7	5.3	163.0
FIELD	PURPLE	200	8.3	2.7	61.0	5.7	87.7
HIGH TUNNEL	CONV	200	14.0	4.0	43.0	3.7	266.7
HIGH TUNNEL	KPF-4	200	52.0	16.3	63.3	11.7	324.0
HIGH TUNNEL	PURPLE	200	3.3	2.3	49.7	4.0	219.7
LSD _(0.05)			NS	NS	NS	NS	NS

ENVIR	GENOTYPE	FERTIIZER	UNIFL	BIFL	TRFL	BRCH	VINL
5MAT							
FIELD	CONV	0	33.7	6.0	44.3	6.0	180.3
FIELD	KPF-4	0	78.7	2.3	12.0	8.0	131.7
FIELD	PURPLE	0	10.3	4.0	50.3	4.7	114.7
HIGH							
TUNNEL	CONV	0	7.7	5.3	71.7	6.0	298.7
HIGH							
TUNNEL	KPF-4	0	71.2	11.3	43.3	7.7	266.3
HIGH							
TUNNEL	PURPLE	0	4.0	0.0	47.7	4.0	272.3
FIELD	CONV	100	38.0	5.7	42.3	5.3	178.7
FIELD	KPF-4	100	62.3	7.0	14.0	6.0	178.0
FIELD	PURPLE	100	6.0	1.7	63.0	5.3	114.3
HIGH							
TUNNEL	CONV	100	16.0	5.0	46.3	6.7	305.3
HIGH							
TUNNEL	KPF-4	100	64.3	15.3	75.7	12.7	312.0
HIGH							
TUNNEL	PURPLE	100	4.7	0.0	89.0	6.0	295.0
FIELD	CONV	200	19.0	7.0	51.3	6.0	151.3
FIELD	KPF-4	200	54.0	7.3	43.7	7.3	195.7
FIELD	PURPLE	200	8.7	2.3	83.7	7.0	106.0
HIGH							
TUNNEL	CONV	200	10.0	3.7	64.3	5.7	294.7
HIGH							
TUNNEL	KPF-4	200	59.3	20.3	70.3	11.0	357.0
HIGH							
TUNNEL	PURPLE	200	3.7	0.7	69.3	5.3	259.3
LSD _(0.05)			NS	NS	NS	NS	NS
6MAT							
FIELD	CONV	0	25.7	3.7	52.0	6.0	198.3
FIELD	KPF-4	0	77.7	4.1	19.0	10.3	167.7
FIELD	PURPLE	0	8.0	1.7	62.7	5.7	119.7
HIGH							
TUNNEL	CONV	0	0.3	0.0	24.3	5.0	297.7
HIGH							
TUNNEL	KPF-4	0	85.0	8.3	39.0	21.0	264.3
HIGH							
TUNNEL	PURPLE	0	1.0	0.0	34.7	3.0	264.0
FIELD	CONV	100	25.7	6.3	64.3	41.3	206.7
FIELD	KPF-4	100	81.3	5.0	23.0	6.7	198.7
FIELD	PURPLE	100	3.3	1.0	59.0	4.7	120.0
HIGH							
TUNNEL	CONV	100	9.7	2.3	36.7	6.3	283.7

HIGH TUNNEL	KPF-4	100	61.7	12.3	56.0	17.0	359.7
HIGH TUNNEL	PURPLE	100	0.0	0.0	56.3	5.7	316.7
FIELD	CONV	200	13.0	2.0	62.0	5.7	168.0
FIELD	KPF-4	200	54.0	5.3	61.3	9.0	211.0
FIELD	PURPLE	200	8.3	1.7	69.3	8.0	109.0
HIGH TUNNEL	CONV	200	1.0	0.0	22.3	5.3	292.3
HIGH TUNNEL	KPF-4	200	48.3	6.0	49.3	14.3	362.0
HIGH TUNNEL	PURPLE	200	1.0	0.7	30.7	5.7	268.0
LSD _(0.05)			NS	NS	NS	NS	NS
7MAT							
FIELD	CONV	0	27.7	8.0	72.3	7.0	231.0
FIELD	KPF-4	0	91.7	5.7	35.0	9.0	177.7
FIELD	PURPLE	0	8.7	2.3	69.3	6.3	127.0
HIGH TUNNEL	CONV	0	0.0	0.0	5.0	6.0	296.7
HIGH TUNNEL	KPF-4	0	92.7	8.3	28.7	22.7	275.0
HIGH TUNNEL	PURPLE	0	0.7	0.0	12.3	1.7	260.3
FIELD	CONV	100	27.7	6.7	65.7	7.3	238.3
FIELD	KPF-4	100	89.3	13.3	25.7	8.0	223.0
FIELD	PURPLE	100	8.0	3.0	66.7	5.7	127.7
HIGH TUNNEL	CONV	100	14.7	2.3	26.0	9.0	288.0
HIGH TUNNEL	KPF-4	100	42.3	8.7	42.3	17.3	341.3
HIGH TUNNEL	PURPLE	100	0.0	0.0	15.0	5.3	312.0
FIELD	CONV	200	9.0	4.3	78.3	6.3	191.7
FIELD	KPF-4	200	57.7	7.0	71.7	9.7	214.7
FIELD	PURPLE	200	2.3	0.0	50.3	6.0	98.0
HIGH TUNNEL	CONV	200	4.3	1.7	17.0	7.3	291.3
HIGH TUNNEL	KPF-4	200	54.0	5.3	61.3	9.0	229.3
HIGH TUNNEL	PURPLE	200	0.0	0.0	9.0	4.0	235..7
LSD _(0.05)			NS	NS	NS	5.8	NS

ENVIR	GENOTYPE	FERTIIZER	FRWT	DRWT	MC
FIELD	CONV	0	40.7	9.2	79.1
FIELD	KPF-4	0	73.7	16.1	79.2
FIELD	PURPLE	0	80.3	22.4	72.1
HIGH TUNNEL	CONV	0	62.3	17.5	72.5
HIGH TUNNEL	KPF-4	0	88.3	20.4	77.2
HIGH TUNNEL	PURPLE	0	85.7	22.1	74.4
FIELD	CONV	100	74	16.2	78.2
FIELD	KPF-4	100	82	19.3	76.0
FIELD	PURPLE	100	95	22.9	76.0
HIGH TUNNEL	CONV	100	99	18.3	80.0
HIGH TUNNEL	KPF-4	100	92	22.2	75.4
HIGH TUNNEL	PURPLE	100	113.7	28.7	74.8
FIELD	CONV	200	59	13.4	77.2
FIELD	KPF-4	200	69.3	8.3	88.5
FIELD	PURPLE	200	96.3	21.6	77.7
HIGH TUNNEL	CONV	200	79	21.3	73.0
HIGH TUNNEL	KPF-4	200	77.7	17.9	77.3
HIGH TUNNEL	PURPLE	200	108.7	20.2	81.4
LSD _(0.05)			NS	NS	NS