UNIVERSITY OF ZULULAND

Effect of NPK basal fertilizer, nitrogen top dressing and season on growth and yield of *Cucurbita argyrosperma*

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DECLARATION

The research described in this dissertation was carried out in the Department of Botany at the University of Zululand, KwaDlangezwa, under the supervision of Dr N.R. Ntuli. This study has not otherwise been submitted in any form for any degree or diploma at any University. Where use has been made of work of others, it is duly acknowledged in the text.

Zoliswa Mbhele

I certify that the above statement is correct.

Dr N.R. Ntuli

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ABSTRACT

Cucurbita argyrosperma is grown for its edible shoots, flowers, immature and mature fruits as well as seeds, which provide proteins, vitamins, edible oils and minerals. The objective of this study was to investigate the effect of NPK basal fertilizer, nitrogen top dressing and seasonal variation on the agronomic traits of *C. argyrosperma*. Plants were grown at 0; 150; 300 and 450 kg ha^{-1} NPK basal fertilizer and 0; 150 and 300 kg ha^{-1} nitrogen top dressing during warm and cold seasons. The application of 300 kg ha^{-1} NPK and 300 kg ha^{-1} N resulted in longer vines and larger fruit size. Thicker stems, heavier fresh shoots and roots, vigorously growing first, second and third leaves from the apex, were recorded after an application of 450 kg ha^{-1} NPK and 300 kg ha^{-1} N. In the presence of NPK, any addition of nitrogen resulted in numerous leaves with more chlorophyll content. The application of 150 NPK and 300 N resulted in higher root moisture content and more staminate flowers. Numerous pistillate flowers were recorded at a combination of 450 kg ha^{-1} NPK and 150 kg ha^{-1} N fertilizers. However, 100 seed mass was not affected by the application of either NPK or nitrogen top dressing. In the warm season plants had thicker stems; numerous leaves; fast-growing first and second leaves from the apex; higher total chlorophyll content as well as heavier fresh and dry shoots and roots. Plants in the warm season (23° – 33°) also produced numerous staminate flowers; many fruits per plant with larger sizes; numerous and heavier seeds per fruit; and heavier hundred seed mass. Plants grown during cold season (16° – 25°) had their third leaf from the apex growing faster, as well as higher shoot and root moisture content. Season did not affect shoot growth as well as the number of pistillate flowers. A positive definition with PCA and significant positive correlation of all measured agronomic traits except shoot and root moisture content show them as proper traits to measure growth and yield in *C. argyrosperma*. Cluster analysis showed that the application of 300 and 450 kg ha^{-1} NPK fertilizer at varying nitrogen top dressing concentrations during warm and cold seasons, respectively, can promote growth and yield of *C. argyrosperma*.

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CONFERENCE PRESENTATIONS

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ABBREVIATIONS

ANOVA:	Analysis of variance
b:	breath
Ca:	Calcium
chl:	chlorophyll
cm:	centimetre
DMSO:	dimethylsulfoxide
E:	East
FM:	fresh mass
FT:	fertilizer treatment
g:	grams
ha:	hacters
K:	Potassium
Kg:	kilograms
L:	length
LA:	leaf area
LAN:	Limestone Ammonium Nitrate
Mg:	Magnesium
mm:	millilitres
N:	Nitrogen top dressing
NPK:	Nitrogen Phosphorus Potassium
P:	Phosphorus
RCBD:	Randomised Complete Block Design

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S:	South
ssp:	sub species
W:	width
WAP:	weeks after planting

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Chapter 1

1 Introduction

Cucurbita argyrosperma Huber belongs to the Cucurbitaceae family (Martins *et al*., 2015). It is commonly referred to as cushaw and was formerly known as *Cucurbita mixta* (Sanjur *et al*., 2002). The local name for *C. argyrosperma* in Northern KwaZulu-Natal is *Isiphama* (Ntuli *et al*., 2016). It is one of the five domesticated *Cucurbita* species including *C. pepo; C. maxima; C. moschata* and *C. ficilifolia*. *Cucurbita argyrosperma* was recently reported for the first time as a food source in South Africa (Ntuli, 2013).

In South Africa (Ntuli, 2013) and Mexico (Montes-Hernandez *et al*., 2005) the shoots, flowers, immature and mature fruits as well as seeds are eaten. The shoots and fruits provide essential proteins and vitamins for diet in rural and urban families. The seeds are a source of edible oils, potassium, phosphorus and magnesium and they also contain high amounts of other trace minerals. *Cucurbita argyrosperma* is common both in production for market and for home consumption in Mexico (Montes-Hernandez *et al*., 2005).

Cucurbita species are subtropical to tropical plants that grow well in summer or warm climatic conditions (Bavec *et al*., 2007). They can be cultivated off-season if there is proper fertilizer application and irrigation. In the warm season, *Luffa acutangular and Citrullus lanatus* are characterised with an increase in vine length, number of branches, shoot dry mass, number of leaves, number of fruits per vine and leaf area (Hilli *et al*., 2009 and Noh *et al*., 2013) grown in the warm season. Heat causes reduction in chlorophyll content in *Cucumis sativus* (Yang *et al*., 2000). Fruit mass, seed mass, seed yield per hectare of *L. acutangular* (Hilli *et al*., 2009) and the soluble solid content of *C. lanatus* (Noh *et al*., 2013) grown in the warm season increase significantly.

Application of NPK fertilizer in *Luffa acutangula* and and *Cucurbita pepo* increased vine length, number of primary branches per vine, number of leaves as well as shoot fresh and dry mass (Hilli *et al*., 2009 and Oloyede *et al*. 2013a). It also increased the leaf area of *Cucumis sativus* (Eifediyi and Remison, 2009). The application of N and NPK fertilizers causes high production of total chlorophyll content in the leaves of *C.*

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pepo convar. pepo var. *styriaca* (Aroiee and Omidbaigi, 2004) and *Momordica dioica* (Vishwakarma *et al*., 2007) respectively. In *C. sativus* increased levels of N and P in an NPK fertilizer application induced the production of numerous staminate and pistillate flowers (Umamaheswarappa *et al*., 2005). In *Ipomoea batatas* NPK fertilizer application increases leaf N, P, K, Ca and Mg concentration (Agbede, 2010).

Application of NPK fertilizer also increased the following fruit and seed characteristics: number of fruits per vine per hectare; and 100-seed mass in *L. acutangula* (Hilli *et al*., 2009), *C. sativus* (Arshad *et al*., 2014), *Cucurbita moschata* (Manjunath Prasad *et al*, 2007) and *C. pepo* (Oloyede *et al*., 2013b). Treatment of *C. pepo convar. pepo* var. *styriaca* plants with N fertilizer causes the production of high seed oil content (Aroiee and Omidbaigi, 2004). Proximate value of carbohydrates in young and mature fruits of *C. pepo* increases with an increase in NPK fertilizer application, but values of protein, fat ash and crude fibre decreases (Oloyede, 2012).

Cucurbita argyrosperma is one of leafy vegetables that are grown at household level in northern KwaZulu-Natal. It is preferred over other cucurbits because of its fruit taste and texture (Ntuli *et al*., 2016). However, much research on growth and yield has been conducted on other domesticated *Cucurbits,* but it is still limited on *C. argyrosperma*. Since *C. argyrosperma* had shown low yield in its recent first report in South Africa, studies to improve its growth and yield are essential.

1.1 Aim and objectives of the study

The aim of this study was to investigate the effect of NPK fertilizer, nitrogen top dressing and seasonal variation on the agronomic traits of *C. argyrosperma*. These traits include: plant height; growth in leaf area; shoot growth; leaf chlorophyll content; shoot and root fresh mass, dry mass and moisture content; fruit mass and size; as well as seed mass and size.

The specific objectives were to determine:

- level(s) of NPK fertilizer application (0; 150; 300 or 450 kg ha^{-1}) that promote(s) growth and yield in *C. argyrosperma.*

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- nitrogen top dressing level(s) (0; 150 and 300 kg ha^{-1}) that is/are suitable for growth and yield in *C. argyrosperma.*
- a season that enhances growth and yield in *C. argyrosperma.*

1.2 Research hypotheses

- High level(s) of NPK basal fertilizer enhance(s) growth and yield in *C. argyrosperma*.
- Growth and yield in *C. argyrosperma* is promoted by high quantity of nitrogen top dressing.
- Warm season promotes growth and yield in *C. argyrosperma.*

1.3 Structure of dissertation

Chapter 1 presents the general introduction which includes problem statement, research aims and the proposed hypotheses. **Chapter 2** provides an in-depth examination of existing literature on the effect of NPK fertilizer and season on vegetative and reproductive traits of *C. argyrosperma*. The general methodology adopted in this study is described in **Chapter 3**.

Chapter 4 presents and analyzes the results obtained in the current study. The results are discussed in **Chapter 5**. **Chapter 6** is a synopsis of the critical findings emanating from the results and the contribution of the study to existing knowledge on the application of NPK basal fertilizer and nitrogen top dressing in the warm and cold seasons. It also makes recommendations on appropriate NPK fertilizer application and season of growing *Cucurbita argyrosperma* for better growth and yield.

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Chapter 2

2 Literature review

This section provides an overview of previous knowledge, evidence and introduces the framework for the study that comprises the focus of the research. The focal purpose of the literature review was to examine prior studies on knowledge that supported the research undertaken. There was a research gap on growth of the *Cucurbita argyrosperma* and not much has been done on this vegetable. Therefore information was drawn from other Cucurbita species.

2.1 Taxonomy and morphology of *Cucurbita argyrosperma*

Cucurbita argyrosperma Huber belongs to the order Cucurbitales, family Cucurbitaceae, and tribe Cucurbiteae (Jeffrey, 1990). It has two species: *C. argyrosperma* ssp. *argyrosperma* and *C*. *argyrosperma* ssp. *sororia*, where the former subspecies has four varieties: *C*. *argyrosperma* ssp *argyrosperma* var. *argyrosperma*, *C*. *argyrosperma* ssp *argyrosperma* var. *callicarpa*, *C*. *argyrosperma* ssp *argyrosperma* var. *stenosperma* and *C*. *argyrosperma* ssp *argyrosperma* var. *palmieri* (Jarret et al., 2013). There is a wide infraspecific variation in *C*. *argyrosperma*.

The two subspecies of *C. argyrosperma* have wide morphological variations even though they are closely related phylogenetically (Jones, 1992). The leaves of *C. argyrosperma* ssp *sororia* exhibit a marked heteroblasty in leaf shape, in which the early leaves are slightly lobed and are followed by a transition series where they become highly lobed. This was in contrast with *C. argyrosperma* ssp *argyrosperma* which has less-lobed and larger leaves (Jones, 1993). *Cucurbita argyrosperma ssp argyrosperma* is a cultivated cucurbit used for seed and pulp consumption and *C. argyrosperma* ssp *sororia* is a wild weedy cucurbit used for medicinal purposes. A bitter flavour is characteristic of the wild *C. argyrosperma ssp sororia* (Montes-Hernandez *et al*., 2005).

Seeds of *Cucurbita argyrosperma* are usually white or tan. Margins are sometimes the same colour as the center of the seed, little darker, or yellowish to golden (Lira *et*

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al. 1995). Whereas *Cucurbita argyrosperma* ssp *sororia* has numerous small seeds in contrast with *C. argyrosperma* ssp *argyrosperma* which has larger seeds (Paris, 1997). The pedicels of *C. argyrosperma* fruits are very wide and not flared at the base at maturity. This crop is monoecious, producing solitary staminate and pistillate flowers in the axil of leaves (Cuevas-Marrero and Wessel-Beaver, 2008). Every leaf axil bears a flower once flowering commences (Jones, 1995).

2.2 Origin and distribution of *Cucurbita argyrosperma*

Cucurbita argyrosperma is originally from the south of Mexico (Sanjur *et al*., 2002), one of the centers of plant domestication in the world (Zizumbu-Villarreal *et al*., 2014). Together with *C. pepo*, *C. maxima,* and *C. moschata, Cucurbita argyrosperma* was probably the oldest cultivated plant in tropical regions of America (Milani *et al*., 2007). This crop was most likely domesticated from a wild Mexican gourd, *Cucurbita sororia* (Martins *et al*., 2015). The three cultivated varieties of *C. argyrosperma*, namely, *C. argyrosperma* var. *argyrosperma*, *C. argyrosperma* var. *callicarpa* and *C. argyrosperma* var. *stenosperma* are found in areas with hot, fairly dry climate or a well-defined rainy season (Hernandez Bermejo and Leon, 1994). The wild *Cucurbita argyrosperma* ssp *sororia* grows under the same environmental conditions as weed in agricultural fields in Mexico (Lira *et al*., 2009).

2.3 The uses of *Cucurbita argyrosperma*

Among cucurbits *Cucurbita argyrosperma* is one of the five species that have been cultivated and domesticated for many years, mostly for their edible fruits which are known as pumpkins and squash (Gong *et al*., 2013). Both immature and mature fruits and seeds of *Cucurbita* species provide inexpensive sources of proteins and vitamins (Montes-Hernandez *et al*., 2005).

Cucurbita species comprises of overlapping groups of cultivars that yield seed or edible fruits (Abiodun and Adeleke, 2010). Edible seeds and fruits are yielded from *Cucurbita argyrosperma*. The wild and weedy *C. argyrosperma* ssp *sororia* is used in a variety of ways. The nutshell is used as handicraft. Fruits which are thin, greenish-whitish, and coarsely fibrous and bitter (Paris 1997) are for medicinal purposes and fodder (Lira and Caballero, 2002) whereas *C. argyrosperma* ssp *argyrosperma*

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flowers, seeds and fruits are consumed. These can be baked (cooked by dry heat in an oven), boiled or toasted (cook or brown by exposure to a grill, fire, or other source of radiant heat). The seeds which are often an excellent source of protein and fat are also dried and preserved (Zizumbo-Villarreal *et al*., 2014). The fruit is rich in vitamin A, potassium, fibre and carbohydrates (Tunde-Akintunde and Ogunlakin, 2011).

Cucurbit seeds are a rich source of oil and nutrients and can also be consumed as food. The pumpkin seeds contain fatty oil, ß-sitosterol and vitamin E and are also used in certain pharmaceutical products. In Austria and Germany, the oil of pumpkins was used as salad dressing (Sigmund and Murkovic, 2004). Cucurbit seed oil had anti-bacterial, anti-hypercholesterolaemia, anti-hypertension and anti-inflammatory properties (Caili *et al*., 2006).

The oil content of *C. argyrosperma* seeds ranged from 29.1 to 43.3% (Stevenson *et al*. 2007). Jarret *et al*. (2013) concluded that the mean seed oil content of *C. argyrosperma* and *C. moschata* was similar. The seeds of *C. moschata* are nutritious and contain approximately 33.5 % oil and mono unsaturated fatty acids which are beneficial to humans.

2.4 Effect of fertilizer and season

Nitrogen, potassium and phosphorus are the major elements required by plants (Ginindza *et al*., 2015). Many studies have proved that nitrogen, phosphorus and potassium increase the growth and productivity of cucurbits (Oloyede *et al*. 2013b). In cucurbits, insufficient levels of the primary nutrients particularly nitrogen, phosphorus and potassium lead to poor fruit setting and low crop yield and nutritional quality (Oloyede *et al*., 2013b). The soil has to be fertile for cucurbits to produce good yields as the soil can supply a significant portion of the crop's nutrient status (Warncke, 2007). Application of fertilizers is one of the ways in which the nutrient status of the plant and soil can be increased (Ginindza *et al*., 2015; Kolodziej, 2006; Nahed, 2007). Nitrogen is the most important nutrient for plant growth and productivity (Eftekharinasab *et al*., 2011). Smil (2002) estimated that nitrogen fertilizer has contributed about 40% towards the increase in per capita food production in the past 50 years and that its contribution still continues to increase (Erisman *et al*., 2007). Excessive fertilizer application is common among some

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farmers because of their lack of knowledge on fertilizer types and the nutrient requirements of crops (Martinetti and Paganini, 2006). Optimum doses of N and P depend on the length of growing season, soil type, and fertility status of soil, cultivar and environmental factors. All these factors result in marked effect on growth and fruit yield parameters of pumpkin (Manjunath Prasad *et al*., 2008).

Growth season weather conditions can affect crop growth and productivity. Since soil dryness becomes drier as temperature increases, irrigation treatments under such conditions would be expected to leave greater impact on the growing crop (Tan *et al*., 2009). Cucurbits can adapt and grow in a wide range of environmental conditions, from tropical, subtropical, arid deserts and temperate regions (Schwarz et al., 2010; Noh *et al*., 2013). However they are less adapted to temperate regions because of their sensitivity to low temperature and frost. Therefore, a minimal temperature of 18 °C was needed to obtain proper growth (Noh *et al*., 2013). When exposed to very low temperature many horticultural crops originating from sub-tropical areas including Cucurbitaceae suffer physiological disorders which, depending on intensity and length of exposure, subsequently lead to irreversible dysfunction, cell death and finally plant death (Kozik and Wehner 2014; Schwarz et al., 2010). Suboptimal temperature stress often caused heavy yield losses of fruits and vegetables by suppressing plant growth during winter and early spring season (Bai *et al*., 2016). Severe heat and cold were some of the major abiotic stresses that induce severe cellular damage in crop plants (Bita and Gerats, 2013).

The application of fertilizer and season affects growth and yield of cucurbits as follows:

2.4.1 Shoot growth

Trailing growth habit enables cucurbits to exploit the sunlight by producing maximum vine length which can result in better assimilation of carbohydrates during photosynthesis. Cucurbit vines can spread over 15 meters from its stand, covering the soil within 45 days (Oloyede, 2011). Application of NPK fertilizer caused a significant increase in vine length of *Cucurbita pepo* (Oloyede *et al*., 2013a) and vine of *Luffa acutangula* (Hilli *et al*. 2009). Application of nitrogen fertilizer caused the plant height to increase in *Cucurbita pepo* (Ng’etich *et al*., 2013).

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Cucurbits are warm season annuals which grow in hot and humid weather and are very sensitive to low temperature and light intensity. Seasons of the year play an important role when it comes to growth in cucurbits. Hilli *et al*., (2009) showed that vine length was increased in both cold and hot seasons when NPK fertilizer was applied. However, low root zone temperature reduced shoot growth leading to heavy loss of crop productivity (Bai *et al*., 2016).

2.4.2 Stem diameter

Fluctuation in water status caused changes in stem diameter of the plant (Fujita *et al*., 2003). Stem diameter of *Cucurbita moschata* (Okonwu and Mensah 2012), *Telfairia occidentalis* (Edu *et al*., 2015) and *Cucurbita pepo* (Oloyede *et al*., 2012b) increased with application of NPK fertilizer. The increase in the application of nitrogen fertilizer resulted in an increase in stem diameter of *Cucurbita pepo* (Ng'etich *et al*., 2013).

Many *Cucurbita* fields in the mid-Atlantic have plants with weak stems during the cold season due to foliar diseases. However, maintaining healthy stems is one of the most important considerations for good fruit development. Vine diameter of *Cucurbita pepo* increased in warm rather than in cold season (Oloyede *et al*., 2013a).

2.4.3 Number of leaves

The leaf is a very important plant organ where photosynthesis and transpiration occurs. Trailing growth habit enables cucurbits to exploit the sunlight by producing the maximum number of leaves which can result in better assimilation of carbohydrates during photosynthesis (Oloyede, 2011). Application of NPK fertilizer caused a significant increase in vine length of *Cucurbita pepo* (Oloyede *et al*., 2013b). An increase in applied fertilizer levels induced an increase in number of *Luffa acutangula* leaves (Hilli *et al*., 2009).

In the mid-Atlantic, cucurbits have poor foliage during the cold season due to foliar diseases such as powdery and downy mildews.

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2.4.4 Growth of leaf area

Leaf area measurements were required in most plant physiology and agronomic studies (Guo and Sun, 2001). The leaf area of *Cucumis sativus* (Eifediyi and Remison, 2009) and *Ipomoea batatas* (Agbede, 2010) increased when NPK fertilizer is applied and when its levels application increase.

During the vegetative growth phase, suboptimal temperatures resulted in slower leaf expansion (Schwarz *et al*., 2010).Leaf area of *Cucumis sativus* was significantly increased as temperature increased (Noh *et al*., 2013). The leaf chlorophyll content of *Cucumis sativus* which was grown under high temperature was reduced significantly (Yang *et al*., 2000) in contrast with *Cucumis melo* and *Citrullus lanatus* (Inthichack *et al*., 2014).

2.4.5 Chlorophyll content

Leaf colour is a good indication of the chlorophyll content in leaves (Ghanbari *et al*., 2007). It is used as a gauge for plant health (Ali *et al*., 2012). Most of the leaf nitrogen was incorporated in chlorophyll, so quantifying chlorophyll content gave an indirect measure of the nutrient status of a plant (Moran *et al*., 2000). *Momordica dioica* plants treated with NP fertilizer had higher leaf chlorophyll content than untreated plants (Vishwakarma *et al*., 2007) but the opposite was true in *Cucurbita moschata* (Mensah and Okonwu, 2012). Chlorophyll content was directly related to nitrogen leaf concentration as the leaf chlorophyll content of *Cucurbita pepo* increased with increasing nitrogen rates (Aroiee and Omidbaigi, 2004). This resulted in increased photosynthetic rates and vegetative growth (Pandey and Sinha, 2006). Potassium application increased the chlorophyll content in the leaves of *Luffa acutangula* (Hilli *et al*., 2009).

Suboptimal temperature caused a decrease in the photo synthetic rate (Schwarz *et al*., 2010). In plants, acclimation to cold conditions causes reduction in photo synthetic function. A decrease in photosynthetic function was observed in *Pisum sativum* exposed to 5 °C (Humplik *et al*., 2015). Total chlorophyll content of *Cucurbita pepo* increased as temperature increased (Pugliese *et al*., 2012).

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2.4.6 Shoot fresh and dry mass, and moisture content

Fresh and dry weight of *Luffa acutangula* (Hilli *et al*., 2009) and *Cucurbita pepo* (Oloyede *et al*., 2013a) shoots increased with the application of fertilizer.

The difference in temperature affected several characteristics in plants as low temperature disrupted normal cell functions (Lee *et al*., 2002). As a result the leaf and stem dry mass of *Cucumis sativus, Cucumis melo* and *Citrullus lanatus* was increased when temperature increased (Inthichack *et al*., 2014).

2.4.7 Root fresh and dry mass, and moisture content

The application of NPK fertilizer caused an increase in root fresh and dry mass of *Amaranthus caudatus* (Olowoake and Adebayo 2014).Root dry mass of *Solanum melongena* increased significantly when there was an increase in the application of NPK basal fertilizer (Nafui *et al*., 2011).

2.4.8 Number of flowers

Application as well as an increase in the levels of nitrogen and phosphorus application resulted in a significant increase on the number of staminate and pistillate flowers per vine of *Cucumis sativus* (Umamaheswarappa *et al*., 2005) and *Luffa acutangula* (Hilli *et al*., 2009). Better utilization of nitrogen and phosphorus lead to vigorous growth and increased number of pistillate flowers that resulted in higher fruit set and fruit yield in *Luffa acutangula* (Hilli *et al*., 2009). However, the application of varying levels of potassium did not affect flowering of *Cucumis sativus* (Umamaheswarappa *et al*., 2005). High nitrogen application under high temperature promoted an increase in the number of staminate flowers but reduction in the number of pistillate flowers per vine resulted in low fruit set (Hilli *et al*., 2009). Excessive application of nitrogen fertilizer also delayed the production of pistillate flowers and decreased fruit set (Oloyede *et al*., 2012b). Phosphorus is a very important element in plant production as it increased the production of pollen (Ortiz and Gutierrez, 1999).

In cucurbits, the warm season caused a delay in the formation of pistillate flowers and their development to anthesis but staminate flowers were not affected. This resulted in a decline in the number and size of *C. pepo* fruits in particular (Wein *et*

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al., 2004). Flower induction was driven by environmental changes and occured in short day plants as day length and temperature declined. However, flower induction was primarily induced by photoperiodic reduction rather than low night temperatures (Atkinson *et al*., 2013). More staminate and pistillate flowers were recorded in the cold than in the warm season from *Cucumis sativus* (Nwofia *et al*., 2015).

2.4.9 Number, mass and size of fruits

In cucurbits, insufficient levels of the primary nutrients particularly nitrogen, phosphorus and potassium lead to poor fruit setting, low crop yield and low nutritional quality (Oloyede *et al*., 2013b). Phosphorus and potassium application was essential for the setting, development and storage of cucurbit fruits (Oloyede *et al*., 2013a). An increase in the phosphorus application resulted in the reduction of proximate composition in fruits of *Trichosanthes cucumerina* (Oloyede and Adebooye, 2005). Applications of higher dose of NPK fertilizers lead to numerous fruits per vine in cucurbits (Manjunath Prasad *et al*., 2007; Vishwakarma *et al*., 2007). Also the application of phosphorus fertilizer induced the production of numerous and large *Cucumis melo* fruits (Mendoza-Cotez *et al*., 2014). In *Cucurbita pepo,* fertilizer application and increase in fertilizer rates resulted in enhanced fresh fruit mass, fruit length and fruit circumference of *Cucurbita pepo* (Oloyede *et al*., 2013a) and *Cucumis sativus* (Eifediyi and Remison, 2009). Inadequate or excess applications of phosphorus lead to the production of under-developed fruits which ultimately reduced the yield (Hilli *et al*., 2009).

Fruit length and diameter was associated with the final fruit size and it depended on the number of cell divisions that occur in the developing fruit (Villalobos, 2006). There was usually a drastic improvement in crop quality and quantity when appropriate fertilizers were added (Nahed, 2007). Fruit length and diameter were associated with the final fruit size and it depends on the number of cell divisions that occur in the developing fruit (Villalobos, 2006).

A study on *Solanum lycopersicum* showed that severely low temperature conditions resulted in a decrease in the number of fruits (Schwarz *et al*., 2010). Hilli *et al*. (2009) pointed out that fruit set and fruit mass was increased in both hot and cold seasons

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when NPK fertilizer was applied. The fruit mass of *C. argyrosperma* in summer was higher than in winter season (Nunez-Grajeda and Garza-Ortega 2005).

2.4.10 Number, mass and size of seeds

The number of seeds produced in a fruit depends on the species. *Cucurbita argyrosperma* and the wild species *Cucurbita pepo* var *texana* produced more than 250 seeds per fruit (Merrick, 1990; Avila-Sakar *et al*., 2001). Seed yield per unit area is a product of the multiplication of three components namely number of fruits per unit area, number of seeds per fruit and mean weight of the individual seed (Nerson, 2007). Seed yield of field grown cucurbits was greatly affected by environmental conditions, irrigation and fertilization management as well as pest and disease control (Nerson 2005a, 2005b).

Seed yield of *Cucurbita pepo* was directly proportional to the size of its fruits, thus the heavier the fruit the higher the seed yield per hectare (Oloyede *et al*., 2013b). Application of NPK fertilizer as well as increase in its levels resulted in the higher seed yield per vine and hectare of *Cucurbita moschata* (Manjunath Prasad *et al*., 2007); *Luffa acutangular* (Hilli *et al*., 2009) and *Cucurbita pepo* (Oloyede *et al.*, 2013b). In *C. moschata*, higher seed yield per ha^{-1} (541.0 kg) was observed at the fertilizer level of 150:60:60 kg NPK per ha^{-1} followed by 125:50:50 kg NPK per ha^{-1} and 100:40:40 kg NPK per ha^{-1} which record 379 kg per ha^{-1} and 284 kg per ha^{-1}, respectively (Manjunath Prasad *et al*., 2007). Also, a significant increase in seed yield of *Luffa acutangular* was evident when NPK fertilizer application increased from lower (50:50:50 kg ha^{-1}), to medium (75:75:75 kg ha^{-1}) and to high (100:100:100 kg ha^{-1}) levels (Hilli *et al*., 2009).

Hilli *et al*., 2009 found that seed yield levels of *Luffa acutangula* were higher in summer. The significant increase in the seed yield could be due to increased growth parameters, increased translocation of photosynthates and assimilation in the development of seed yield components. In the study by Nunez-Grajeda and Garza-Ortega (2005) seed mass of *Cucurbita argyrosperma* increased in summer and declined in winter. A higher amount of seed oil content was noted in the seeds of *Cucurbita pepo* grown in high temperature (Nederal *et al*., 2014).

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2.5 Food security and crop production

The latest South African estimates for food security suggested that between 41% and 51.6% of households were food insecure (Labadarios *et al*., 2008). Another study showed that one out of three households was at risk of becoming food insecure (Labadarios *et al*., 2008). Hunger, malnutrition and rural poverty are some of the current challenges facing South Africa. There is a decline in the use of wild vegetables which may have caused an increase in the incidences of nutritional deficiencies. Insipte of the importance of these species in household security, their cultivation is still very uncommon (Lewu and Mavengahama, 2010). In South Africa, various crops are grown depending on the soil, climate and water availability (Voster, 2007). Leafy vegetable marketing is limited and mostly restricted to dried products (Vorster *et al*., 2002; Hart and Vorster, 2006). The role of leafy vegetables in the food consumption patterns in South African households is highly variable and mostly depends on such factors as poverty status, degree of urbanisation, distance to fresh produce markets and time of year.

In South Africa, members of the Cucurbitaceae family are very popular leafy vegetables and are amongst the few African leafy vegetables that are cultivated (Jansen van Rensburg *et al*., 2007). Cucurbits fruits are extensively used as vegetables both in immature and mature stages. The immature fruits which are called courgettes are consumed as a vegetable, boiled, fried or steamed in combination with the shoots (Mananjunath Prasad *et al*., 2007). When matured, the fruits are called pumpkin and are usually peeled and cooked (Oloyede *et al*., 2012b). Collecting and cultivating leafy vegetables is widespread among rural South Africans (Jansen van Rensburg *et al*., 2004, 2007). Even though western influences have considerably modified food consumption patterns, some of the food plants were actively cultivated while naturally occurring ones were nurtured in homestead food gardens (Modi *et al*., 2006). Major constraints facing the production of plant crops were poor seed quality, pest and diseases, drought and poor marketing channels (Vorster, 2007).

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2.6 Summary

This review discussed the effect of NPK fertilizer application in varying seasons on growth and yield of Cucurbitaceae species. The literature review also reflected on the optimal fertilizer application and the recommended season for better growth and yield of these species. Current knowledge shows that there is a research gap particularly on growth and yield studies in *C. argyrosperma*. Such research has focused mainly on other domesticated *Cucurbits*. South Africans are vulnerable to food insecurity. Therefore proper application of fertilizer in different seasons has a potential in *C. argyrosperma* being grown throughout the year and contributing to household food and nutritional security. Chapter 3 will provide a description of the study area, seed collection, land preparation, experimental layout, data collection and data analysis.

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Chapter 3

3 Materials and Methods

3.1. Study area

The research was conducted at the University of Zululand Agricultural Research station situated in Empangeni, uMhlathuze Municipality, KwaZulu-Natal province in South Africa (28 85 00° S; 31 83 33° E). Empangeni normally receives about 948 mm of rain per year, with most rainfall occurring mainly during mid-summer (SA Explorer, 2014).

Figure 3.1: The map indicates the study area at University of Zululand, situated in uMhlathuze Municipality, KwaZulu-Natal, South Africa.

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3.2 Seed collection

Seeds belonging to the same landrace were collected from the community members of uMkhanyakude district where *C. argyrosperma* is grown in South Africa. A pre-trial was conducted in uMkhanyakude district and then *C. argyrosperma* seeds were collected from one crop to ensure uniformity and genetic purity.

3.3 Soil sample analysis and land preparation

The soil samples were collected randomly (up to 20 cm soil depth) across the experimental area before ploughing using an auger. The soil samples were combined to create composite soil samples which were analysed for soil fertility status at the Cedara Experiment Station in Pietermaritzburg as described by Sharma *et al.* (2014).

The land was prepared using a tractor for ploughing and disking. The experiment was laid out in a randomized complete block design (RCBD) having three replicates (Figure 3.2).

3.4 Experimental layout and planting

Each plot had four rows of 6 m length and distance between plants was 1 m giving a total of 7 plants per row. The distance between adjacent plots within a replicate was 1 m and the distance between replicates was 1.5 m to avoid nitrogen fertilizer drift. Three seeds per hole were sown and the seedlings were thinned to one plant per stand at two weeks after planting (WAP) or once the seedlings had developed two or three leaves (Oloyede *et al*., 2013b; Arshad *et al*., 2014; Oloyede *et al.*, 2014). Weeding was done and insecticide applied when necessary. All plants were well irrigated to provide optimum growing conditions.

NPK basal fertiliser 2:3:4 (30) was applied at four levels as follows: **(B1)** 0kg ha^{-1}; **(B2)** 150 kg ha^{-1}; **(B3)** 300 kg ha^{-1} and **(B4)** 450 kg ha^{-1}. Nitrogen top dressing (LAN at 28% N) was applied at three levels as follows: **(N1)** 0 kg ha^{-1}; **(N2)** 150 kg ha^{-1} and **(N3)** 300 kg ha^{-1}. Therefore treatment combinations were: **B1N1; B1N2; B1N3; B2N1; B2N2; B2N3; B3N1; B3N2; B3N3; B4N1; B4N2; B4N3.**

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The seasonal variation was investigated by planting during winter period (March – August) with temperature range (16° – 25°) and in spring / summer (September – January) with temperature range (23° – 33°). The experiments were repeated in such a way that each season was replicated twice (March – June 2015 and 2016; November – February 2015 and 2016).

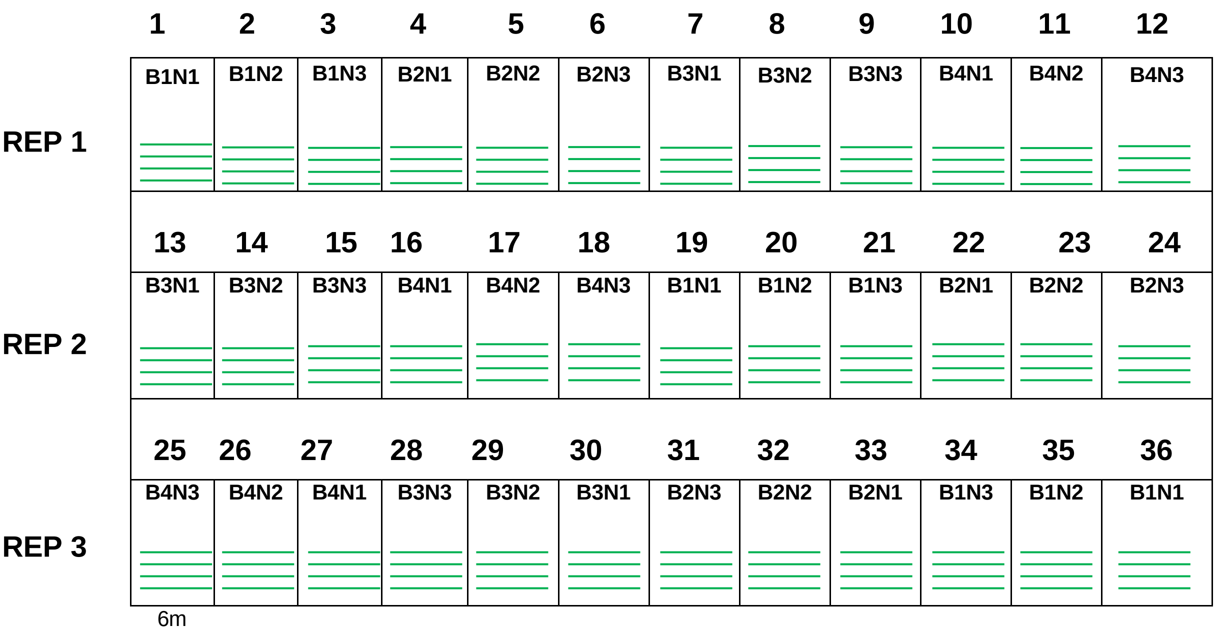

Figure 3.2: The randomised complete block design for the effect of NPK fertilizer and nitrogen top dressing on the growth of *Cucurbita argyrosperma.*

3.5 Data collection

Data was collected with focus on the following areas: shoot growth, growth in leaf area, fresh mass, dry mass, moisture content, shoot mineral content, number of flowers, fruit analysis and seed analysis. Data collection of the vegetative traits started when the plants had developed four leaves, and continued at seven day intervals. Data collection commenced from five weeks after planting to seven weeks except for fruit – related data which proceeded to week eight. Six plants per treatment were collected and used for determination of plant growth (Yang *et al*., 2009).

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3.5.1 Shoot growth and leaf area

Vine length (m), shoot growth (cm) was measured with a ruler or tape. The unfolded first, second and third leaf from the shoot apex was used to determine leaf growth within seven days. Leaf area was measured non-destructively using a ruler. Leaf length (L) was measured from lamina tip to the intersection of the lamina and petiole along the lamina midrib. Leaf width (W) was measured from tip to tip between the widest lamina lobes. Length and (L) and width (W) was used to calculate leaf area.

Equation for calculating leaf area: LA = l x b

Shoot length was measured at Initial (from leaf one to apex) and final growth was measured with a ruler within seven days. Growth in leaf area was measured at Initial and final leaf area of leaf one, two and three from the apex and was measured with a ruler within seven days.

Percentage shoot growth or growth in leaf area was calculated using the following formula:

Final vine length – Initial vine length X 100 / Initial vine length

Final leaf area – Initial leaf area X 100 / Initial leaf area

3.5.2 Fresh mass, dry mass and moisture content

Harvested plants had their shoots and roots separated. Excess soil was washed with tap water and the plant was blot dried. Fresh mass (FM) was determined by a balance. Shoot and root samples were dried in an oven at 70 ˚C for 72 hrs until they reached constant weight. The proportional difference in weight was converted to percentage and expressed as percent moisture content (Adebooye and Oloyede, 2007; Oloyede *et al*., 2013a; Cho *et al*., 2007).

3.5.3 Chlorophyll content

Leaf chlorophyll concentration was made using the destructive method which was laboratory based. Total leaf chlorophyll content was extracted on the third leaf from

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the apex using dimethylsulfoxide (DMSO). Approximately 100 mg total Chlorophyll was extracted from the leaf sample. When the extractions were complete, samples were transferred to disposable polystyrene cuvettes and into the spectrophotometer.

Total chlorophyll was calculated using Arnon's equation:
Arnon's (1949) equations total Chl (g l^{-1}) = 0.0202 A_{663} + 0.00802 A_{645}.

The Chlorophyll concentration of the extract calculated from this equation was converted to leaf Chlorophyll content (Richardson *et al*., 2001).

3.5.4 Number of flowers

The number of staminate and pistillate flowers per plant was assessed by visual count at the same intervals (Wehner and Gunner, 2004; Islam *et al*., 2014).

3.5.5 Fruit number, mass and size

At harvest, the numbers of fruits per plant were counted on the remaining plants which reached maturity. The mass (g), diameter (cm) and length (cm) of mature fruits were determined using a balance, Vernier callipers and a ruler, respectively (Enujeke, 2013).

3.5.6 Seed number, mass and size

The numbers of fully developed seeds per fruit were documented. The total and 100 seed mass as well as seed size (length x breadth x thickness) were also determined.

3.6 Data analysis

Collected data were analysed by ANOVA using genstat. Duncan's method (DMRT) was used to separate means. The relationships between the agronomic traits were analysed by principal component analysis (PCA) using XLSTAT software. Scatter plots of the first two principal component scores were created. Hierarchiral clustering examination with the Euclidean distance using the principal components scores and the Wards technique as the process of linkage was used to assign a set of

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individuals to a particular treatment. Significance evaluation was accepted at $P \leq 0.05$ and $P \leq 0.01$. Findings regarding the response of various agronomic traits to different fertilizer treatments and seasons will be presented in Chapter 4.

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Chapter 4

4 Results

4.1 Shoot growth response to different fertilizer treatments and seasons

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on the growth percentage of *C. argyrosperma* shoots was recorded from four to five; five to six and six to seven weeks after planting.

4.1.1 Shoot growth response to different fertilizer treatments in the warm season

When the NPK basal fertilizer was not applied (zero NPK) and also kept at 300 kg ha^{-1} (300 NPK), the application of 300 kg ha^{-1} nitrogen top dressing (300 N) resulted in significantly high shoot growth, from four to five weeks after planting (Table 4.1). When the NPK basal fertilizer was 150 kg ha^{-1} (150 NPK), the addition of nitrogen top dressing resulted in longer vines. However, at the NPK basal fertilizer of 450 kg ha^{-1} (450 NPK), any addition of nitrogen top dressing did not affect the shoot growth. At constant 150 kg ha^{-1} nitrogen top dressing (150 N) application, shoots grew much faster only at 150 NPK. When nitrogen top dressing application was kept at 300 kg ha^{-1}, vines grew longer in all NPK basal fertilizer treatments, except 450 kg ha^{-1}.

The application of only 300 N resulted in longer vines, from five to six weeks after planting (Table 4.1). However, at fixed 150 and 300 NPK, the addition of nitrogen top dressing resulted in significantly longer vines. Also, at constant zero; 150 and 300 N, the significant increase in shoot growth was only recorded at 450 NPK application.

Vines grew significantly longer from six to seven weeks after planting with the addition of 150 kg ha^{-1} nitrogen top dressing but in the absence of NPK basal fertilizer. However, when the NPK basal fertilizer was kept constant at 300 kg ha^{-1} and 150 kg ha^{-1} nitrogen top dressing added, the opposite was recorded.

Table 4.1: Shoot growth percentage (%) response as influenced by different fertilizer application in different seasons

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
4 – 5	**0**	80.05 ± 3.50 def	74.54 ± 2.79 ef	124.64 ± 12.71 a	69.24 ± 2.31 f	69.68 ± 4.86 f	85.28 ± 9.07 cdef
WAP	**150**	78.57 ± 1.60 def	118.54 ± 7.46 abc	129.26 ± 6.41 a	82.14 ± 5.68 cdef	91.35 ± 13.44 cde	87.90 ± 7.21 cdef
	300	69.50 ± 12.60 f	86.29 ± 4.78 cdef	120.66 ± 5.18 ab	98.90 ± 4.76 cde	86.67 ± 3.19 cdef	84.90 ± 3.23 cdef
	450	83.08 ± 1.87 cdef	91.23 ± 5.40 cde	98.90 ± 4.76 cde	96.40 ± 12.61 cde	102.18 ± 11.23 bcd	122.62 ± 11.66 ab
5 – 6	**0**	512.83 ± 24.52 ghi	622.60 ± 9.77 efghi	695.66 ± 22.44 cdef	512.37 ± 52.99 ghi	563.70 ± 42.48 fghi	716.23 ± 64.24 bcdef
WAP	**150**	476.96 ± 22.06 i	690.79 ± 25.16 cdef	670.46 ± 42.09 cdefg	662.46 ± 40.06 cdefgh	888.76 ± 119.34 abc	646.67 ± 39.93 defghi
	300	494.86 ± 39.35 hi	692.39 ± 44.63 cdef	753.79 ± 64.09 bcde	967.39 ± 66.70 ab	972.39 ± 46.97 ab	1047.04 ± 98.60 a
	450	715.77 ± 32.79 bcdef	755.24 ± 18.43 bcde	828.99 ± 54.60 bcd	930.16 ± 95.40 ab	957.34 ± 39.14 ab	1059.62 ± 141.72 a
6 – 7	**0**	1016.80 ± 118.52 h	1357.62 ± 146.23 cdefg	1032.85 ± 82.98 gh	1037.06 ± 82.45 gh	1133.44 ± 134.22 fgh	1278.42 ± 190.60 defgh
WAP	**150**	1479.93 ± 120.87 cdef	1430.64 ± 132.52 cdef	1656.21 ± 157.94 bcd	1378.53 ± 117.56 cdef	1476.59 ± 98.12 cdef	1458.77 ± 99.57 cdef
	300	1808.70 ± 150.42 bc	1388.57 ± 104.99 cdef	2218.57 ± 184.47 a	1451.19 ± 133.04 cdef	1391.73 ± 89.04 cdef	1579.89 ± 105.22 cde
	450	1282.90 ± 101.31 defgh	1160.51 ± 53.50 efgh	1147.39 ± 45.97 fgh	1498.64 ± 70.16 cde	1515.74 ± 76.15 cde	1980.99 ± 130.09 ab

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test

In the absence of nitrogen top dressing and in cases where it was constant at 300 kg ha^{-1}, the application of 300 NPK, followed by 150 NPK caused the highest shoot growth.

4.1.2 Shoot growth response to different fertilizer treatments in cold season

A combination of 450 NPK and 300 N caused the shoot growth to increase significantly, from four to five weeks after planting (Table 4.1). Longer vines were also obtained in an application of either 300 or 450 NPK only. At a fixed 150 and 300 N application, shoot growth was higher when 450 NPK was present.

The application of only 300 N enhanced shoot growth, from five to six weeks after planting (Table 4.1). At zero; 150 and 300 N, vines grew significantly longer in the presence of 300 NPK.

At constant 450 NPK application, significantly longer vines were caused by the application of 300 N, from six to seven weeks after planting (Table 4.1). In the absence of nitrogen fertilizer top dressing, any applied amount of NPK basal fertilizer resulted in vigorous shoot growth.

4.1.3 Shoot growth as influenced by the interaction of season and fertilizer

Plants grown with 150 NPK and 300 N; 300 NPK and 300 N; and only 300 N, produced significantly longer vines in the warm than in cold season, from four to five weeks after planting (Table 4.1). However, more shoot growth was recorded in the cold season from plants which were grown with only 300 NPK and a combination of 450 NPK and 300 N.

Insignificant differences in shoot growth were recorded in the absence of NPK basal fertilizer and a variation in nitrogen top dressing in both the warm and cold season, from five to six weeks after planting (Table 4.1). Plants grown with 150 NPK; 300 NPK; 300N; 300 NPK and 150 N; and 450 NPK and 300 N produced significantly longer vines in cold than in warm season.

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Significantly longer vines were recorded from plants grown in the warm season with 300 NPK and 300 N, from six to seven weeks after planting. However, a combination of 450 NPK and 300 N resulted in plants with significantly longer vines in cold season.

4.2 The effect of fertilizer treatment and season on stem diameter of *C. argyrosperma*

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on stem diameter of C*. argyrosperma* was observed during the warm season and cold season at five, six and seven weeks after planting.

4.2.1 Stem diameter in response to different fertilizer treatments in the warm season

The addition of only 300 N caused a significant increase in the stem diameter, at five weeks after planting (Table 4.2). The stem diameter was much thicker at constant 150 NPK when 150 and 300 N was added. However, insignificant differences in stem diameter were observed in an application of constant 300 and 450 NPK and a variation in nitrogen top dressing. Plants grown with only 300 and 450 NPK had significantly thicker stems. There was an increase in stem thickness at constant application of 150 N to 150; 300 and 450 NPK. Further, a constant application of 300 N, to 300 and 450 NPK resulted in thicker stems.

Stems became significantly wider only at the fixed application of 450 NPK when there was an addition of 300 kg ha^{-1} nitrogen top dressing (300 N), at six weeks after planting. When there was no nitrogen top dressing larger stem diameter were obtained at an application of 150; 450 and 300 NPK basal fertilizer, respectively. However, the stem diameter at 150 N increased when 150; 300 and 450 NPK was applied. Much thicker stems were obtained at constant 300 N when 300 and 450 NPK was added.

Table 4.2: Influence of NPK basal fertilizer, nitrogen top dressing and season on the diameter (mm) of *C. argyrosperma* stems

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	**150**	**300**	**0**	**150**	**300**
5 WAP	**0**	12.67 ± 1.43 gh	12.83 ± 0.74 fgh	20.00 ± 1.29 abc	10.33 ± 0.95 h	11.33 ± 0.61 h	12.67 ± 0.76 gh
	150	14.67 ± 1.31 efg	21.83 ± 0.75 abc	18.17 ± 1.49 cd	12.33 ± 1.02 gh	14.83 ± 0.75 efg	15.50 ± 0.67 def
	300	22.67 ± 0.67 ab	24.00 ± 0.52 a	23.00 ± 0.77 a	17.33 ± 1.02 cde	19.33 ± 1.31 bc	21.67 ± 0.80 abc
	450	22.67 ± 1.09 ab	22.67 ± 1.09 ab	24.00 ± 0.97 a	20.00 ± 0.52 abc	20.00 ± 1.37 abc	21.33 ± 0.84 abc
6 WAP	**0**	17.67 ± 1.54 hi	17.83 ± 0.91 hi	20.00 ± 1.37 gh	14.67 ± 1.23 j	13.33 ± 0.49 j	15.17 ± 0.17 ij
	150	22.00 ± 0.68 efg	24.83 ± 1.28 bcdef	24.33 ± 0.76 cdef	17.17 ± 0.91 hi	17.17 ± 1.01 hi	21.67 ± 0.61 fg
	300	27.83 ± 0.91 b	26.50 ± 1.65 bc	27.83 ± 1.40 b	22.33 ± 1.43 efg	25.00 ± 1.03 bcde	24.17 ± 1.51 cdef
	450	23.00 ± 1.98 defg	25.83 ± 1.66 bcd	31.50 ± 1.45 a	20.33 ± 0.33 gh	23.17 ± 0.75 defg	26.00 ± 0.73 bcd
7 WAP	**0**	24.17 ± 1.42 ghi	24.17 ± 0.79 ghi	28.50 ± 1.86 def	20.67 ± 0.67 i	22.17 ± 0.60 hi	24.50 ± 0.43 fghi
	150	25.83 ± 1.68 fgh	33.00 ± 1.32 bcd	31.00 ± 1.79 bcde	24.33 ± 0.95 fghi	27.17 ± 1.22 efg	28.33 ± 0.61 defg
	300	33.50 ± 1.52 bcd	35.17 ± 2.57 bc	33.83 ± 2.12 bcd	31.83 ± 1.56 bcd	34.67 ± 1.05 bc	33.33 ± 1.15 bcd
	450	31.83 ± 1.94 bcd	34.67 ± 2.60 bc	42.67 ± 1.28 a	30.33 ± 1.50 cde	32.33 ± 1.86 bcd	39.00 ± 0.44 ab

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test.

There were no significant differences observed at zero and 300 NPK when nitrogen top dressing varied at seven weeks after planting. However, the stem diameter increased significantly at 150 NPK with any addition of nitrogen top dressing. Thicker stems obtained at constant 450 NPK application were caused by the addition of 300 N. When there was no nitrogen top dressing, the application of 300 and 450 NPK resulted in much thicker stems. The stem diameter increased significantly when nitrogen top dressing was kept constant at 150 kg ha^{-1} and 150; 300 and 450 NPK was added. However, when nitrogen top dressing was 300 kg ha^{-1}, the largest stem diameter was obtained when 450 NPK was applied.

4.2.2 Stem diameter response to different fertilizer treatments in cold season

The stem diameter increased significantly when 150 and 300 N were fixed and there was an application of 150 and 300 NPK at five weeks after planting (Table 4.2). Insignificant differences were recorded when NPK basal fertilizer was kept constant at zero and 450 kg ha^{-1} and nitrogen top dressing varied.When there was no nitrogen top dressing applied, thicker stems resulted with the addition of 450 NPK. At fixed 150 N, an increase in stem diameter was caused by the application of 300 and 450 NPK. However, when 300 N was kept constant, an increase in stem diameter was influenced by the application of 300 and 450 NPK.

Insignificant differences were recorded when there was no application of NPK basal fertilizer and a variation in nitrogen top dressing at six weeks after planting. However, when 150 and 450 NPK application was fixed, the addition of 300 N caused significantly thicker stems. At the constant application of 300 NPK, the addition of 150 and 300 N resulted in larger stems. When nitrogen top dressing was kept constant at zero; 150 and 300 kg ha^{-1}, the addition of 300 and 450 NPK basal fertilizer resulted in thicker stems.

When zero and 150 NPK was kept constant, the application of 150 and 300 N resulted in larger stems, at seven weeks after planting. However, when there were 450 NPK, the application of 300 N resulted in a significant increase in stem diameter. There were no significant differences observed at 300 NPK when nitrogen top dressing varied. An increase in stem diameter was observed when zero and 150 N were kept constant and there was an addition of 300 and 450 NPK. However, much thicker stems were obtained when 300 N was fixed and 450 NPK was added.

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4.2.3 Stem diameter as influenced by the interaction of season and fertilizer

Fertilizer treated plants at different levels and combinations had significantly larger stem diameters in the warm than in the cold season at five weeks after planting (Table 4.2). Untreated plants as well as fertilizer treated plants at different levels and combinations had thicker stems in the warm than in the cold season at six weeks after planting.

Differences were not significant in all fertilizer treatments for both warm and cold season at seven weeks after planting. However, the only exception was when both NPK basal fertilizer and nitrogen top dressing were 150 kg ha^{-1} each, significantly thicker stems were recorded from plants grown only in the warm season.

4.3 The effect of fertilizer and season on the number of leaves in *C. argyrosperma*

At five, six and seven weeks after planting (WAP), the effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on the number of leaves of *C. argyrosperma* was recorded, during the warm and cold seasons.

4.3.1 The number of leaves in response to different fertilizer treatments in the warm season

Differences were not significant in the number of leaves with variation in the amount of nitrogen top dressing and when the basal NPK fertilizer was kept constant at five weeks after planting (Table 4.3). Numerous leaves were obtained when 300 N was kept contant and there was an application of 450 NPK. The number of leaves increased significantly at 150 N when there was an addition of 300 and 450 NPK basal fertilizer.

The number of leaves increased only at 450 NPK when there was no nitrogen top dressing applied at six weeks after planting. When zero and 150 N was fixed, the addition of 450 NPK resulted in more leaves. There was an increase in the number of leaves at constant application of 300 N when 300 and 450 NPK was applied.

When the basal NPK basal fertilizer was kept constant, differences were not significant in the number of leaves with the variation in the amount of nitrogen top dressing, at

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seven weeks after planting. The number of leaves increased when there was no nitrogen top dressing but an application of 150; 300 and 450 NPK. At 150 and 300 N, there was a significant gradual increase in the number of leaves when NPK basal fertilizer application was increased from zero; 150; 300 until 450 kg ha^{-1}.

4.3.2 The number of leaves in response to different fertilizer treatments in cold season

There were no significant differences in the number of leaves when the basal NPK fertilizer was kept constant and nitrogen top dressing varied, at five weeks after planting (Table 4.3). When there was no nitrogen top dressing, an increase in the number of leaves was observed only when there was an addition of 150 and 450 NPK. There were significantly more leaves recorded at constant 150 N when 300 NPK was applied. No significant differences were obtained when 300 N was kept constant and the amount of NPK basal fertilizer was increased.

Differences were not significant in the number of leaves when the basal NPK fertilizer was kept constant with the variation in the amount of nitrogen top dressing, at six weeks after planting. Much more leaves were obtained when there was no nitrogen top dressing but only the application of 300 and 450 NPK. There was an increase in the number of leaves when the application of 150 and 300 N was fixed and there was an addition of 450 NPK.

There were no significant differences in the number of leaves when the basal NPK basal fertilizer was kept constant with variation in the amount of nitrogen top dressing, at seven weeks after planting. A gradual increase in the number of leaves was observed when zero; 150 and 300 N were fixed and NPK basal fertilizer application was increased from zero; 150; 300 and 450 kg ha^{-1}.

Table 4.3: Number of leaves as influenced by different fertilizer application in different seasons

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season(23° - 33°)			Cold Season (16° - 25°)		
		0	**150**	**300**	**0**	**150**	**300**
5	**0**	5.00 ± 0.00 cde	5.00 ± 0.25 cde	5.16 ± 0.16 bcd	4.50 ± 0.22 e	4.50 ± 0.22 e	5.00 ± 0.26 cde
WAP	**150**	5.50 ± 0.22 abc	5.16 ± 0.16 bcd	5.50 ± 0.22 abc	5.17 ± 0.31 bcd	4.83 ± 0.17 de	5.30 ± 0.21 abcd
	300	5.33 ± 0.21 abcd	5.83 ± 0.17 a	5.50 ± 0.22 abc	4.83 ± 0.17 de	5.17 ± 0.31 bcd	5.33 ± 0.21 abcd
	450	5.83 ± 0.16 a	5.66 ± 0.21 ab	5.83 ± 0.16 a	5.83 ± 0.21 abcd	5.00 ± 0.00 cde	5.33 ± 0.21 abcd
6	**0**	6.83 ± 0.47 ghij	7.00 ± 0.57 fghij	7.33 ± 0.76 efghij	6.17 ± 0.40 j	6.50 ± 0.62 ij	7.30 ± 0.67 efghij
WAP	**150**	8.00 ± 0.00 defg	7.66 ± 0.21 defghi	8.30 ± 0.33 cde	7.00 ± 0.52 fghij	6.67 ± 0.42 hij	7.00 ± 0.45 fghij
	300	8.50 ± 0.22 bcde	8.33 ± 0.33 cde	8.66 ± 0.33 bcd	7.83 ± 0.48 defgh	7.00 ± 0.26 fghij	8.17 ± 0.40 def
	450	10.66 ± 0.42 ab	9.66 ± 0.33 a	9.50 ± 0.34 abc	8.17 ± 0.48 def	8.17 ± 0.31 def	8.33 ± 0.33 cde
7	**0**	16.83 ± 0.16 d	17.33 ± 0.43 d	17.50 ± 0.22 d	11.83 ± 0.48 e	12.33 ± 0.84 e	13.67 ± 0.60 e
WAP	**150**	25.83 ± 0.60 b	26.50 ± 0.22 b	26.50 ± 0.22 b	21.67 ± 1.15 c	21.67 ± 1.02 c	22.33 ± 1.05 c
	300	30.16 ± 0.40 a	29.50 ± 0.22 a	29.50 ± 0.22 a	25.00 ± 0.58 b	24.83 ± 0.54 b	24.83 ± 0.60 b
	450	31.16 ± 0.40 a	31.00 ± 0.51 a	31.00 ± 0.77 a	26.17 ± 0.40 b	26.33 ± 0.61 b	26.17 ± 0.60 b

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

4.3.3 Interaction effect of season and fertilizer on the number of leaves

At five weeks after planting, significantly numerous leaves were obtained in the warm than in the cold season, from plants grown with a combination of 300 NPK and 150 N, as well as 450 NPK and 150 N (Table 4.3). Fertilizer treated plants at different levels and combinations had significantly more leaves in the warm than in cold season at six weeks after planting.

Untreated plants as well as fertilizer treated plants at different levels and combinations had more leaves in the warm than in the cold season, at seven weeks after planting.

4.4 The effect of fertilizer and season on growth percentage of *C. argyrosperma* leaves

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on leaf growth percentage of first, second and third leaf from the apex, was recorded from four to five, five to six and six to seven weeks after planting, during both warm and cold seasons

4.4.1 Growth in leaf area in response to different fertilizer treatments in the warm season

The application as well as the increase in the amount of only NPK basal fertilizer resulted in significant growth percentage of the first leaf from the apex, from four to five weeks after planting (Table 4.4). The same was recorded when NPK basal fertilizer was increased and 300 N was fixed. An application of 300 and 450 NPK also caused significantly faster growth of the first leaf when a constant 150 N was applied. Larger leaves were also recorded when only 300 N was applied compared with untreated plants. The application of 300 N to 150 NPK resulted in plants with significantly broarder first leaves. The application of nitrogen top dressing to 300 NPK also resulted in larger first leaves. The application as well as the increase in the amount of nitrogen top dressing when 450 NPK was kept constant resulted in significantly broader first leaves.

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The application of only 150 N resulted in significant growth percentage of the second leaf, from four to five weeks after planting (Table 4.4). An addition of 150 NPK also caused significantly faster growth of the second leaf when a constant 150 and 300 N was applied. Larger leaves were also recorded when 300 and 450 NPK was applied, with an addition of 300 N. Larger leaves were also recorded when only 300 and 450 NPK was applied. The application of 150 and 300 N resulted in significantly broader second leaves when there was an application of NPK basal fertilizer.

The application of 300 N to zero; 150; 300 and 450 NPK resulted in a significant growth percentage of the third leaves from four to five weeks after planting (Table 4.4). The application as well as increase in the amount of only NPK basal fertilizer caused significantly broader leaves than leaves of untreated plants. Singificantly broader leaves were also recorded when the applied NPK basal fertilizer was increased and 150 and 300 N was kept constant, respectively.

Plants treated with only 450 NPK had significant growth of the first leaf from the apex when compared with untreated plants, from five to six weeks after planting (Table 4.4). Also, only the increase to 450 NPK basal fertilizer resulted in broader leaves when 150 and 300 N was kept constant, respectively. Any application as well as increase in the amount of nitrogen top dressing to either untreated or NKP fertilizer treated plants did not cause any significant changes in the first leaf growth.

The application as well as the increase in the amount of only NPK basal fertilizer did not result in any significant growth of the second leaf from the apex, from five to six weeks after planting (Table 4.4). However, only when 300 N was applied to 450 NPK, were significantly larger leaves recorded. Any application as well as increase in the amount of nitrogen top dressing to either untreated or NPK basal fertilizer treated plants insignificantly affected growth of the second leaf.

Larger leaves were recorded when only 300 N was applied on the third leaf, from five to six weeks after planting (Table 4.4). The application as well as increase in the amount of only nitrogen top dressing did not result in any significant growth of the third leaf when 150 and 450 NPK basal fertilizer was kept constant. The application of 300 N to 300 NPK resulted in significantly broader first leaves.

Table 4.4: Leaf growth percentage (%) of *C. argyrosperma* as influenced by NPK basal fertilizer, nitrogen top dressing and season

4-5 WAP	Nitrogen Top Dressing (kg ha^{-1})	NPK Basal FT (kg ha^{-1})			
		0	150	300	450
1st Leaf Warm Season (23° - 33°)	**0**	17602.50 ± 168.47 ijk	22816.67 ± 1290.50 h	25450.00 ± 51.64 g	28446.17 ± 752.98 ef
	150	18831.67 ± 1648.74 hijk	22312.50 ± 132.33 h	35213.17 ± 516.90 a	29509.60 ± 341.70 cde
	300	22405.00 ± 597.73 h	29412.50 ± 1093.83 cde	33314.70 ± 1302.42 ab	33769.50 ± 2968.26 ab
Cold Season (16° - 25°)	**0**	11800.00 ± 642.78 no	18485.00 ± 790.93 hijk	28900.00 ± 1637.27 cdef	23837.33 ± 817.86 h
	150	15787.00 ± 442.04 jkl	22521.67 ± 1000.70 h	29366.67 ± 1932.47 cde	28175.00 ± 1441.15 ef
	300	14515.00 ± 1125.83 lm	26323.33 ± 1940.09 fg	26205.83 ± 1048.92 fg	31562.33 ± 1048.92 cde
2nd Leaf					
Warm Season (23° - 33°)	**0**	9983.00 ± 621.86 op	10793.77 ± 305.05 op	18600.00 ± 568.04 hikj	21027.50 ± 830.84 h
	150	13092.42 ± 841.71 mn	18450.00 ± 464.76 hijk	18097.83 ± 845.45 ijk	23745.00 ± 580.62 h
	300	12326.33 ± 540.74 no	23765.00 ± 1132.24 h	19275.17 ± 1717.53 h	24995.00 ± 475.96 g
Cold Season (16° - 25°)	**0**	10865.00 ± 21.95 nop	18300.00 ± 1387.32 hijk	31825.00 ± 1990.80 bc	20146.33 ± 666.12 h
	150	15929.17 ± 1429.63 ijkl	28500.00 ± 671.32 def	28761.00 ± 2227.11 cdef	33700.00 ± 1451.21 ab
	300	15766.67 ± 2146.07 jkl	28083.33 ± 2031.16 ef	29220.00 ± 1577.21 cde	35460.00 ± 1501.69 a
3rd Leaf					
Warm Season (23° - 33°)	**0**	9075.00 ± 321.39 p	19205.00 ± 205.27 hi	15627.50 ± 355.67 klm	25896.00 ± 621.23 fg
	150	9075.00 ± 412.16 p	18886.70 ± 145.03 hijk	16971.13 ± 261.07 ijkl	28837.50 ±668.09 cdef
	300	14140.27 ± 1015.05 lmn	14543.50 ± 925.51 lm	27966.68 ± 687.55 ef	31697.50 ± 678.42 bcd
Cold Season (16° - 25°)	**0**	9512.33 ± 545.49 op	19000.00 ± 909.12 hij	27366.33 ± 878.38 fg	25428.33 ± 1143.68 g
	150	12483.17 ± 831.90 mno	21150.00 ± 954.81 h	28137.33 ± 1242.27 ef	34362.33 ± 1858.02 a
	300	13950.00 ± 547.84 lmn	24466.67 ± 2248.21 g	28766.33 ± 1808.38 cdef	30600.00 ± 1700.59 cde

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.4: Leaf growth percentage (%) of *C. argyrosperma* as influenced by NPK basal fertilizer, nitrogen top dressing and season (Continued).

5-6 WAP	Nitrogen Top Dressing (kg ha^{-1})	NPK Basal FT (kg ha^{-1})			
		0	150	300	450
1st Leaf Warm Season (23° - 33°)	0	25383.17 ± 706.44 efghijk	31425.00 ± 941.17 cdefghijk	35815.00 ± 1285.22 cdefghi	50701.33 ± 3707.52 abcd
	150	27733.17 ± 266.64 efghijk	38396.50 ± 2398.04 bcdef	42125.00 ± 1514.77 abcde	55693.17 ± 2952.94 ab
	300	27650.00 ± 681.18 efghijk	40300.00 ±1656.84 bcdef	39254.17 ± 2799.34 bcdef	55070.00 ± 3333.12 ab
Cold Season (16° - 25°)	0	19450.00 ± 890.79 hijk	26016.33 ± 1283.64 efghijk	32725.00 ± 1156.54 cdefghi	35910.00 ± 2493.54 cdefghi
	150	26180.00 ± 258.35 efghijk	35075.00 ± 893.82 cdefghi	34300.00 ± 3419.16 cdefghi	37445.83 ± 1993.14 bcdefg
	300	25400.00 ± 461.16 efghijk	46600.00 ± 3582.74 abcd	37005.00 ± 1921.27 cdefgh	37600.00 ± 1722.21 bcdefg
2nd Leaf					
Warm Season (23° - 33°)	0	23008.17 ± 350.14 fghijk	29291.33 ± 1431.87 defghijk	30718.17 ± 851.52 defghijk	36932.33 ± 2462.71 cdefgh
	150	32103.17 ± 337.96 cdefghi	46978.50 ± 1695.80 abcd	40043.17 ± 2639.14 bcdef	52537.33 ± 2330.14 abcd
	300	29037.33 ± 632.11 defghijk	32271.33 ± 1242.91 cdefghi	49066.33 ± 1651.58 abcd	58325.00 ± 3155.67 a
Cold Season (16° - 25°)	0	23383.17 ± 1295.91 fghijk	30766.33 ± 1090.97 cdefghijk	45975.00 ± 903.83 abcd	36110.00 ± 1353.53 cdefghi
	150	32850.00 ± 1514.71 cdefghi	47216.33 ± 1486.07 abcd	41633.17 ± 2508.83 abcdef	47130.00 ± 2358.87 abcd
	300	35160.00 ± 1219.73 cdefghi	37350.00 ± 931.49 bcdefg	46950.00 ± 1809.14 abcd	55060.00 ± 3268.63 ab
3rd Leaf					
Warm Season (23° - 33°)	0	14433.17 ± 520.91 jk	31623.17 ± 884.99 cdefghijk	19075.00 ± 791.96 hijk	23475.00 ± 19.36 fghijk
	150	17913.17 ± 681.08 ijk	28325.17 ± 1441.86 defghijk	36575.00 ± 187.19 cdefgh	35906.17 ± 2511.13 cdefghi
	300	32815.00 ± 216.21 cdefghi	26125.00 ± 529.31 efghijk	59712.33 ± 1033.29 a	37835.00 ± 1540.64 bcdefg
Cold Season (16° - 25°)	0	13250.00 ± 193.65 k	41950.00 ± 3480.69 abcde	42550.00 ±1008.46 abcde	28850.00 ± 376.88 defghijk
	150	19950.00 ± 1711.77 ghijk	38450.00 ± 2205.03 bcdef	29575.00 ± 2632.44 defghijk	43791.33 ± 1187.19 abcde
	300	38316.33 ± 207.50 bcdef	25193.50 ± 951.15 efghijk	49762.50 ± 3104.53 abcd	35665.00 ± 3477.41 cdefghi

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.4: Leaf growth percentage (%) of *C. argyrosperma* as influenced by NPK basal fertilizer, nitrogen top dressing and season (Continued).

6-7 WAP	Nitrogen Top Dressing (kg ha^{-1})	NPK Basal FT (kg ha^{-1})			
		0	150	300	450
1st Leaf Warm Season (23° - 33°)	**0**	25516.33 ± 658.58 mno	29475.00 ± 1208.32 jklm	35990.00 ± 1337.72 ghij	38325.00 ± 4283.97 fghi
	150	29196.17 ± 964.68 jklm	35268.50 ± 837.52 ghij	41433.17 ± 1797.10 efg	55863.17 ± 3097.60 b
	300	30612.33 ± 1521.86 jklm	29325.00 ± 179.00 jklm	41575.00 ± 2991.13 efg	55850.00 ±2656.04 b
Cold Season (16° - 25°)	**0**	19986.83 ± 664.26 op	25325.00 ± 652.37 no	27275.00 ± 1857.40 mn	32008.33 ± 2351.43 jkl
	150	23806.00 ± 989.48 no	29146.00 ± 986.62 jklm	28300.00 ± 1673.92 lm	37110.00 ± 812.75 ghij
	300	22675.67 ± 1008.44 no	30545.00 ± 3216.24 jklm	32741.67 ± 2968.84 jkl	28908.33 ± 1245.62 klm
2nd Leaf					
Warm Season (23° - 33°)	**0**	25033.17 ± 842.38 no	29952.33 ± 2084.44 jklm	37343.17 ± 3001.75 ghij	55648.00 ± 4294.21 cd
	150	31773.50 ± 1934.72 jkl	34290.00 ± 1804.74 ghij	34843.17 ± 1539.73 ghij	57175.00 ± 4477.69 b
	300	33843.50 ± 2031.64 hij	33941.33 ± 181.01 hij	30590.00 ± 1658.01 jklm	56831.00 ± 4146.29 b
Cold Season (16° - 25°)	**0**	22106.33 ± 582.19 no	36340.00 ± 1470.34 ghij	38533.17 ± 1243.74 fgh	36800.00 ± 2343.94 ghij
	150	28119.00 ± 994.57 lm	38900.00 ± 774.60 efg	33083.33 ± 3580.75 ijkl	49675.00 ± 1188.80 d
	300	25914.50 ± 1272.22 mno	33233.17 ±2299.18 ijk	33870.00 ± 1413.97 hij	42007.33 ± 2336.67 ef
3rd Leaf					
Warm Season (23° - 33°)	**0**	6012.17 ± 455.08 q	14750.00 ± 193.65 p	33758.17 ± 965.54 hij	52800.00 ± 2455.71 cd
	150	28750.00 ± 1564.66 klm	26941.33 ±1614.50 mn	50466.33 ± 1824.71 d	41826.17 ± 1607.11 ef
	300	21600.00 ± 200.10 no	31950.00 ± 83.91 jkl	55700.00 ± 2588.44 bc	67283.17 ± 3380.98 a
Cold Season (16° - 25°)	**0**	31971.33 ± 814.23 jkl	43782.00 ± 1471.40 e	48775.00 ± 1716.38 d	43866.33 ± 2875.27 e
	150	34181.00 ± 2133.43 ghij	50333.33 ± 1133.33 d	41350.00 ± 3885.16 efg	45716.33 ± 869.13 e
	300	35702.00 ± 2042.63 ghij	37600.00 ± 2694.53 fghi	41950.00 ± 2281.01 ef	48665.50 ± 1148.01 d

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

A significant growth of the first leaf from the apex was recorded on application of only 300 and 450 NPK fertilizer when compared with untreated plants, from six to seven weeks after planting (Table 4.4). An increase in the amount of NPK basal fertilizer from 300 NPK when 150 and 300 N was kept constant, respectively, resulted in broader leaves. Only the application of nitrogen top dressing to 450 NPK resulted in larger leaves.

Higher growth percentage of the second leaf was recorded when either nitrogen top dressing was applied alone or when added to 450 NPK, from six to seven weeks after planting (Table 4.4). However, an increase in the amount of applied nitrogen top dressing under such conditions did not cause any significant increase of leaf growth. The application as well as the increase in the amount of nitrogen top dressing did not result in any significant growth when a constant 150 and 300 NPK basal fertilizer was applied. The application as well as the increase in the amount of only NPK basal fertilizer resulted in significant growth percentage of the second leaf. However, a 450 NPK application caused significantly faster growth of the second leaf when 150 and 300 N application was constant.

The application as well as the increase in the amount of NPK basal fertilizer and nitrogen top dressing, either alone or combined, resulted in the significant growth percentage of the third leaf, from six to seven weeks after planting (Table 4.4).

4.4.2 Growth in leaf area in response to different fertilizer treatments in cold season

The application of nitrogen top dressing alone or with 450 NPK basal fertilizer resulted in plants with significantly broader first leaves from the apex, from four to five weeks after planting (Table 4.4). However, an increase in the amount of nitrogen top dressing under such conditions did not result in significant leaf growth. Larger leaves were also recorded when 300 N was added to 150 NPK. Larger leaves were also recorded when 150 N was applied to 300 NPK. The application as well as the increase in the amount of NPK basal fertilizer to nitrogen top dressing resulted in significantly broader leaves.

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A minimum of 150 N applied either alone or added to different quantities of NPK basal fertilizer resulted in a significant growth percentage of the second leaf, from four to five weeks (Table 4.4). However, further increase in the amount of applied nitrogen top dressing did not result in a significant leaf growth. Larger leaves were also recorded when only NPK basal fertilizer was applied and increased to the maximum of 300 NPK. The application as well as the increase in the amount of NPK basal fertilizer in the presence of nitrogen top dressing resulted in significantly broader leaves.

An increase in growth percentage of the third leaf was recorded, from four to five weeks after planting when 300 N was applied to zero; 150 and 300 NPK (Table 4.4). The application as well as an increase of NPK basal fertilizer to a maximum of 300 NPK either alone or in the presence of 300 N caused a significantly faster growth of the third leaf. The application as well as the increase in the amount of NPK basal fertilizer when 150 N was kept constant resulted in significantly broader leaves.

Generally, the application as well as the increase in the amount of NPK basal fertilizer and nitrogen top dressing did not result in any significant differences in the first leaf from the apex, from five to six weeks after planting (Table 4.4). However, only the application of 300 N to 150 NPK resulted in significantly broader first leaves.

Generally, the application as well as the increase in the amount of NPK basal fertilizer and nitrogen top dressing did not result in any significant differences in the second leaf, from five to six weeks after planting (Table 4.4). However, the application of 300 N to 450 kg NPK resulted in plants with significantly broader second leaves. Larger leaves were also recorded when only 300 NPK was applied.

A significant growth percentage was recorded in the third leaf when only 300 N was applied, from five to six weeks after planting (Table 4.4). Also, a maximum application of 150 NPK either alone or in the presence of 150 N, resulted in significant leaf growth.

The application as well as the increase in the amount of only NPK basal fertilizer above 300 NPK resulted in significant broader first leaves from the apex, from six seven weeks after planting, when compared with leaves from untreated plants (Table 4.4). Also, broader leaves were recorded when the applied NPK basal fertilizer was increased in the presence of constant 150 N application. The application of 300 N to

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300 NPK resulted in significantly broader leaves. Also, the application of 150 N to 450 NPK resulted with a significantly larger leaf.

The application of only 150 N resulted in a significantly broader second leaf than the control, from six to seven weeks after planting (Table 4.4). Significantly larger leaves were also recorded when nitrogen top dressing was applied and increased in its amount in the presence of 450 NPK. The application as well as the increase in the amount of NPK basal fertilizer, either alone or in the presence of nitrogen top dressing resulted in a significant leaf growth percentage.

The application as well as the increase in the amount of NPK basal fertilizer, either alone or when combined with different constant quantities of nitrogen top dressing resulted in significant growth of the third leaf, from six seven weeks after planting (Table 4.4). Also, the application of 150 N to 150 NPK resulted in plants with significantly broader third leaves. However, a further increase of nitrogen top dressing to 300 N under such conditions resulted in significant leaf growth reduction. Also, a minimum application of 150 N to 300 NPK resulted in significantly broarder leaves. Further, the application of 300 N to 450 NPK enhanced leaf growth percentage.

4.2.3 Growth in leaf area in response to the interaction of season and fertilizer

Fertilizer treated plants at different levels and combinations resulted in significantly higher growth percentage of the first leaf from the apex, from four to five weeks after planting in the warm than in the cold season (Table 4.4). However, there was an exception from plants treated with only 300 NPK. Fertilizer treated plants at different levels and combinations showed the most growth percentage in the second and third leaf only in cold season.

Third leaves of plants treated with only 300 NPK were significantly broader in the cold than in the warm season, from five to six weeks after planting. From six to seven weeks after planting fertilizer treated plants at different levels and combinations had significantly more growth percentage in the first and second leaf in the warm than in the cold season. However, in the third leaf, plants treated with zero and 150 NPK had more

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growth in the cold than in the warm season and those treated with 300 N and 450 NPK had more growth in warm than cold season.

4.5 Chlorophyll content response to different fertilizer treatments and seasons

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on the total chlorophyll content of *C. argyrosperma* was recorded at four, five, six and weeks after planting (WAP), during both the warm and cold season.

4.5.1 Chlorophyll content response to different fertilizer treatments in the warm season

When there was zero; 300 and 450 NPK, the addition of nitrogen top dressing fertilizer did not cause any significant differences in total chlorophyll content, four weeks after planting (Table 4.5). When there was 150 NPK, the application of nitrogen top dressing fertilizer resulted in leaves with significantly high chlorophyll content. When the nitrogen top dressing was not applied, 150 NPK resulted in leaves with higher chlorophyll content than other treatments. However in both 150 and 300 N application, any variation in basal fertilizer application did not influence the leaf chlorophyll content.

The application of 450 NPK and 300 N resulted in leaves with higher chlorophyll content than those treated with 150 N, at five weeks after planting. However, the leaves that resulted from the plants that were grown when zero; 150 and 300 NPK was fixed but had an increase in nitrogen application, did not differ in their total chlorophyll content. When nitrogen top dressing was not applied, zero NPK showed a significant decrease in the chlorophyll content of the leaves. When nitrogen top dressing is applied at 150 kg ha^{-1} (150 N) there was a significant decrease at zero NPK. However when 300 N was applied, an increase in NPK basal fertilizer resulted in no significant differences.

When there was zero; 300 and 450 NPK, an increase in nitrogen top dressing did not cause any significant differences in total chlorophyll content of the leaves, at six

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weeks after planting. When there was no application of nitrogen top dressing, an increase in total chlorophyll content was only observed when 300 NPK was applied.

When 150 N was kept constant, leaves with significantly higher chlorophyll content were in plants treated with 150 NPK than those which were not treated with basal fertilizer. However, at constant application of 300 N, variation in basal NPK fertilizer application resulted in leaves that do not differ significantly in their chlorophyll content.

When there was an absence of NPK basal fertilizer, there was a significant increase in total chlorophyll content at 150 and 300 N, at seven weeks after planting. When there was 150; 300 and 450 NPK, the leaf chlorophyll content did not differ significantly with varying application of nitrogen fertilizer. When nitrogen top dressing was not applied (zero N), the highest chlorophyll content was obtained from the leaves treated with 300 and 450 NPK followed by 150 NPK and the least was at zero NPK fertilizer. At a fixed 150 N application, the chlorophyll content was the highest at 450 NPK followed by 150 NPK and then zero NPK. At constant 300 N, the application of NPK basal fertilizer resulted in leaves with higher chlorophyll content.

4.5.2 Chlorophyll content response to different fertilizer treatments in cold season

When there was zero; 150 and 450 NPK, the addition of nitrogen top dressing fertilizer did not cause any significant differences in total chlorophyll content, at four weeks after planting (Table 4.5).A significant increase in total chlorophyll content was recorded when there was no application of nitrogen top dressing. When there was 150 and 300 N application, no significant difference in the total chlorophyll content of the leaves was recorded.

Table 4.5: Leaf total chlorophyll content (g/L x 10^{-4}) response towards NPK basal fertilizer and nitrogen top dressing application in the warm and cold season

NPK Basal FT (kg ha^{1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	**150**	**300**	**0**	**150**	**300**
5	**0**	105.9 ± 3.68 b	103.7 ± 5.37 b	129.8 ± 5.67 b	84.6 ± 17.04 b	105.1 ± 24.79 b	107.8 ± 24.21 b
WAP	**150**	290.6 ± 2.60 a	127.2 ± 7.76 b	112.1 ± 3.59 b	125.2 ± 29.94 b	121.8 ± 28.64 b	129.4 ± 31.33 b
	300	136.7 ± 8.91 b	128.4 ± 8.69 b	128.1 ± 4.64 b	131.7 ± 36.16 b	118.9 ± 29.27 b	116.6 ± 26.24 b
	450	130.9 ± 9.45 b	127.1 ± 8.06 b	151.7 ± 13.37 b	192.7 ± 58.11 ab	121.6 ± 29.36 b	122.2 ± 26.29 b
6	**0**	93.8 ± 8.71 efgh	114.2 ± 5.13 cdefg	112.6 ± 8.04 bcdef	74.08 ± 13.52 h	99.56 ± 28.99 defgh	89.32 ± 3.82 fgh
WAP	**150**	121.9 ± 6.08 bcde	131.2 ± 4.39 abc	110.7 ± 4.5 bcdef	88.2 ± 6.6 fgh	82.7 ± 6.26 gh	89.70 ± 3.15 fgh
	300	127.5 ± 4.35 bcd	137.5 ± 8.32 ab	129.2 ± 6.64 abc	96.1 ± 4.27 efgh	95.7 ± 5.90 efgh	103.4 ± 8.61 cdefg
	450	132.4 ± 11.21 ab	126.7 ± 10.24 abc	152.7 ± 15.46 a	105.3 ± 3.90 cdefg	104.6 ± 5.51 cdefg	100.7 ± 5.20 defg
7	**0**	137.5 ± 6.23 fgh	142.3 ± 6.62 defg	149.3 ± 6.36 cdef	100.5 ± 4.47 j	100.2 ± 3.85 j	110.3 ± 6.49 ij
WAP	**150**	159.1 ± 5.25 abcde	175.3 ± 9.83 a	163.8 ± 10.31 abc	119.30 ± 3.21 hij	113.8 ± 6.34 ij	118.2 ± 1.25 hij
	300	170.6 ± 12.76 ab	153.6 ± 13.94 bcdef	159.2 ± 8.02 abcde	100.3 ± 2.96 j	122.4 ± 2.17 ghi	142.14 ± 6.94 defg
	450	161.7 ± 10.74 abcd	163.9 ± 3.05 abc	161.3 ± 7.00 abcd	140.41 ± 5.98 efg	144.5 ± 6.35 cdef	134.67 ± 6.62 fgh
8	**0**	73.41 ± 7.66 cd	109 ± 23.32 cd	99.7 ± 15.79 c	39.2 ± 15.54 e	43.8 ± 17.86 e	39.5 ± 14.80 e
WAP	**150**	163.3 ± 25.79 bc	161.9 ± 10.69 c	198.7 ± 10.43 abc	43.8 ± 18.22 e	58.5 ± 28.32 e	53.8 ± 23.48 e
	300	203.9 ± 6.98 abc	209.8 ± 7.17 abc	207.01 ± 6.17 abc	49.2 ± 20.67 e	57.7 ± 24.84 e	54.7 ± 21.48 e
	450	231.4 ± 6.17 a	235.7 ± 6.36 a	233.4 ± 7.52 ab	67.8 ± 27.63 cde	62.8 ± 25.24 de	58.6 ± 23.24 e

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

At five weeks after planting when there was zero; 150; 300 and 450 NPK, an increase in nitrogen top dressing did not cause any significant differences in the leaves of the plant. When nitrogen top dressing was not applied, the increase in NPK basal fertilizer resulted in an increase in total chlorophyll content. The application of 150 and 300 N did not cause any significant differences with the increase in NPK basal fertilizer application.

When there was an application of 300 NPK, a significant increase in total chlorophyll content was recorded when nitrogen top dressing was not added, at six weeks after planting. Whereas, when there was zero; 150; and 450 NPK, the chlorophyll content did not differ significantly with an increase in nitrogen top dressing. When 150 and 300 NPK were fixed, and there was an increase in the application of nitrogen top dressing, there were no significant differences observed.

An increase in both NPK basal fertilizer and nitrogen top dressing did not result in any significant differences in total chlorophyll content of the leaves, at seven weeks after planting.

4.5.3 Interaction effect of season and fertilizer on the chlorophyll content

Total leaf chlorophyll content of plants grown with only 150 NPK basal fertilizer was significantly higher in the warm than in the cold season, at five weeks after planting (Table 4.5). Fertilizer treated plants at different levels and combinations had significantly more total chlorophyll in the warm than in the cold season, at six weeks after planting. At seven and eight weeks after planting, untreated plants as well as fertilizer treated plants at different levels and combinations had total chlorophyll only in the warm season.

4.6 A response of shoot fresh and dry mass, and moisture content of *C. argyrosperma* towards fertilizer treatments and season

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on shoot fresh and dry mass (g), and moisture content (%) of *Cucurbita argyrosperma* was recorded at five, six and seven weeks after planting (WAP), during both the warm and cold seasons.

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4.6.1 Shoot fresh mass response to different fertilizer treatments in the warm season

In the absence of NPK basal fertilizer, any addition of nitrogen top dressing resulted in an increase in shoot fresh mass, at five weeks after planting (Table 4.6a). However, there were no significant differences observed when 150 and 300 NPK was applied and nitrogen top dressing varied. When 450 NPK was added, there was an increase in shoot fresh mass when 300 N was applied. There was a gradual increase shoot fresh mass when no nitrogen top dressing was added. The increase was from 150 and 300 NPK up to 450 NPK with the highest shoot fresh mass. When 150 and 300 N was kept constant, the application of 150; 300 and 450 NPK resulted in an increase in shoot fresh mass.

When zero and 450 NPK was kept constant, the addition of 300 N resulted in the highest amount in shoot fresh mass. Shoot fresh mass increased significantly when 150 NPK was kept constant and no nitrogen top dressing was added. However, when 300 NPK was applied, any addition of nitrogen top dressing resulted in an increase in shoot fresh mass. There was a significant increase in shoot fresh mass when there was an absence of nitrogen top dressing but an addition of 150 and 450 NPK. When 150 N was kept constant, the application of 300 and 450 NPK resulted in an increase in shoot fresh mass. However, shoot fresh mass increased significantly when 300 N was kept constant and there was an application of 300 and 450 NPK.

Differences were not significant in shoot fresh mass at constant zero; 150; 300 and 450 NPK with the variation in the amount of nitrogen top dressing, at seven weeks after planting. There was an increase in shoot fresh mass when zero and 150 N was kept constant and an application of 150; 300 and 450 NPK was applied. At constant 300 N application, the addition of 300 and 450 NPK caused an increase in shoot fresh mass.

Table 4.6a: Influence of different fertilizer treatments and seasons on shoot fresh mass (g) per plant of *Cucurbita argyrosperma*

Shoot fresh mass (g) NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1}) Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	**150**	**300**	**0**	**150**	**300**
5 WAP	**0**	3.36 ± 0.43 h	13.02 ± 0.45 e	12.95 ± 0.69 e	1.01 ± 0.40 i	4.94 ± 0.205 gh	5.51 ± 0.41 g
	150	13.43 ± 0.70 e	14.11 ± 0.70 e	13.07 ± 0.59 e	9.93 ± 0.70 f	10.61 ± 0.69 f	10.13 ± 0.19 f
	300	13.17 ± 1.19 e	14.08 ± 1.15 e	13.77 ± 0.85 e	9.67 ± 1.19 f	9.61 ± 0.60 f	10.97 ± 0.48 f
	450	22.15 ± 0.59 bc	22.29 ± 0.33 ab	24.46 ± 0.30 a	18.81 ± 0.53 d	18.92 ± 0.60 d	20.96 ± 0.30 d
6 WAP	**0**	19.08 ± 1.06 jk	19.45 ± 0.51 jk	23.37 ± 0.72 fg	14.89 ± 1.06 m	15.95 ± 0.51 lm	19.92 ± 0.72 ij
	150	25.78 ± 0.80 cde	22.49± 1.19 gh	22.19± 0.65 gh	22.28 ± 0.80 gh	17.77 ± 1.71 kl	18.70 ± 0.65 jk
	300	20.16 ± 1.98 hij	24.81 ± 3.81 efg	26.56 ± 2.46 de	14.72 ± 1.10 m	29.73 ± 0.27 b	24.71 ± 1.59 def
	450	25.13 ± 1.38 def	30.32 ± 1.67 b	33.41 ± 0.74 a	22.64 ± 1.38 ghi	27.41 ± 0.87 c	30.50 ± 0.75 b
7 WAP	**0**	42.94 ± 2.02 hi	51.91 ± 4.15 fgh	49.03 ± 3.38 ghi	39.44 ± 2.01 i	48.41 ± 4.15 ghi	49.19 ± 4.98 ghi
	150	60.46± 4.35 bcdef	66.07± 2.30 abcde	57.58± 5.32 cdefg	56.96 ± 4.35 efg	67.76± 5.67 abcd	57.07± 4.40 defg
	300	68.25 ± 4.57 abc	73.37 ± 3.19 a	73.95 ± 3.45 a	64.76± 4.57 abcde	69.87 ± 3.19 ab	70.79 ± 3.45 ab
	450	73.35 ± 3.12 a	71.66 ± 4.12 a	71.43 ± 3.82 a	72.68 ± 2.34 a	68.61 ± 4.12 abc	73.04 ± 2.02 a

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test.

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Table 4.6b: Influence of different fertilizer treatments and seasons on shoot dry mass (g) per plant of *Cucurbita argyrosperma*

Shoot dry mass (g) NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
5 WAP	**0**	1.68 ± 0.38 fg	2.41 ± 0.22 ef	2.09 ± 0.28 f	0.89 ± 0.02 i	1.30 ± 0.09 ghi	0.87 ± 0.04 i
	150	3.91 ± 0.26 c	4.11 ± 0.20 c	3.01 ± 0.41 de	1.52 ± 0.07 fgh	1.53 ± 0.07 fgh	1.01 ± 0.04 hi
	300	1.55 ± 0.15 fgh	3.08 ± 0.15 d	4.05 ± 0.48 c	1.30 ± 0.15 ghi	1.39 ± 0.07 ghi	1.70 ± 0.01 fg
	450	6.98 ± 0.18 a	6.08 ± 0.20 b	6.53 ± 0.44 ab	1.22 ± 0.01 ghi	1.29 ± 0.03 ghi	1.43 ± 0.07 ghi
6 WAP	**0**	3.36 ± 0.43 e	2.37 ± 0.36 f	5.19 ± 0.24 c	1.17 ± 0.06 g	1.39 ± 0.06 g	1.43 ± 0.07 g
	150	5.77 ± 0.19 bc	3.56 ± 0.24 de	4.07 ± 0.31 d	0.98 ± 0.00 g	1.02 ± 0.02 g	0.97 ± 0.02 g
	300	2.71 ± 0.27 f	10.99 ± 0.31 a	5.78 ± 0.40 bc	1.42 ± 0.03 g	1.03 ± 0.02 g	1.01 ± 0.02 g
	450	6.24 ± 0.35 b	10.67 ± 0.08 a	10.96 ± 0.33 a	1.32 ± 0.02 g	2.39 ± 0.09 f	2.27 ± 0.15 f
7 WAP	**0**	15.99 ± 0.95 kl	23.12 ± 1.13 defgh	17.49 ± 0.84 jkl	6.86 ± 0.37 m	14.86 ± 1.13 l	9.23 ± 0.83 m
	150	25.73 ± 1.26 bcde	27.49 ± 0.95 bc	25.61 ± 1.61 bcdef	17.47 ± 1.26 jkl	19.23 ± 0.95b hijk	18.71 ± 1.17 ijkl
	300	26.84 ± 1.76 bcd	32.88 ± 0.89 a	32.23 ± 0.80 a	18.58 ± 1.76 ghij	23.55 ± 1.39 cdefg	23.80 ± 0.78 cdefg
	450	26.64 ± 1.28 bcd	28.55 ± 2.22 ab	28.65 ± 1.90 ab	19.08 ±1.06 ijk	22.15 ± 1.23 efghi	21.74±1.18 fghi

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.6c: Influence of different fertilizer treatments and seasons on shoot moisture content (%) of *Cucurbita argyrosperma*

Moisture content (%) NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23°- 33°)			Cold Season (16°- 25°)		
		0	150	300	0	150	300
5	0	60.30 ± 2.29 i	81.57 ± 1.31 c	81.33 ± 1.23 cd	12.87 ± 1.05 j	73.16 ± 3.08 efg	83.78 ± 1.54 c
WAP	150	70.80 ± 1.51 gh	70.60 ± 1.82 gh	76.80 ± 3.04 de	84.42 ± 0.99 c	85.03 ± 1.68 c	89.99 ± 0.53 ab
	300	85.68 ± 1.20 bc	76.42 ± 0.27 ef	70.23 ± 3.67 gh	85.52 ± 2.65 bc	85.14 ± 1.44 c	84.40 ± 0.67 c
	450	68.48 ± 0.37 h	73.49 ± 0.73 efg	71.83 ± 1.06 fgh	93.50 ± 0.18 a	93.18 ± 0.17 a	93.16 ± 0.34 a
6	0	81.64 ± 2.24 k	87.74 ± 1.93 hi	77.60 ± 1.54 l	91.98 ± 0.67 def	91.24 ± 0.48 fg	92.74 ± 0.51 bcdef
WAP	150	77.60 ± 0.44 l	84.13 ± 0.78 jk	81.66 ± 1.32 k	95.57 ± 0.17 abc	93.95 ± 0.69 abcde	94.75 ± 0.25 abcd
	300	86.08 ± 1.64 ij	66.97 ± 0.70 m	77.86 ± 1.79 l	90.15 ± 0.68 gh	96.47 ± 0.07 a	95.81 ± 0.29 ab
	450	75.96 ± 1.41 l	62.74 ± 2.38 n	67.80 ± 0.33 m	94.07 ± 0.33 abcde	91.27 ± 0.32 ef	92.54 ± 0.50 cdef
7	0	62.82 ± 0.71 ghi	57.47 ± 1.31 jkl	63.82 ± 2.03 fgh	82.55 ± 0.69 a	68.66 ± 2.57 bc	80.62 ± 2.02 a
WAP	150	59.02 ± 1.01 jkl	58.39 ± 0.27 jkl	56.81 ± 0.48 kl	69.01 ± 1.99 cde	71.03 ± 1.75 bc	66.86 ± 1.73 def
	300	60.59 ± 0.89 hij	56.67 ± 0.53 kl	55.89 ± 2.57 l	71.46 ± 0.91 bc	66.38 ± 0.69 defg	65.96 ± 2.04 fg
	450	63.69 ± 0.51 fghi	60.37 ± 1.19 hijk	59.97 ± 1.11 ijk	73.82 ± 0.74 b	67.12 ± 2.15 efg	70.30 ± 1.21 bcd

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

4.6.2 Shoot fresh mass response to different fertilizer treatments in cold season

An increase in shoot fresh mass was observed in the absence of NPK basal fertilizer when nitrogen top dressing application was increased, at five weeks after planting (Table 4.6a). However, there were no significant differences observed when 150 and 300 NPK was kept constant and nitrogen top dressing varied. At constant 450 NPK, the highest amount in shoot fresh mass was influenced by the addition of 300 N. There was a gradual increase in shoot fresh mass at constant zero; 150 and 300 N when NPK basal fertilizer was added. The increase was from 150 NPK with the least weight; followed by 300 and 450 NPK with the highest shoot fresh mass.

The highest amount in shoot fresh mass was recorded from plants grown when zero and 450 NPK was kept constant and 300 N was applied, at six weeks after planting. No significant differences were recorded at 150 NPK when nitrogen top dressing varied. However, shoot fresh mass increased significantly when 300 NPK was kept constant and nitrogen top dressing was increased. There was an increase in shoot fresh mass in the absence of nitrogen top dressing when 150 and 450 NPK was added. When 150 N was kept constant, the application of 300 and 450 NPK basal fertilizer resulted in an increase in shoot fresh mass. An increase in shoot fresh mass at 300 N was observed only when 300 and 450 NPK was applied.

Differences were not significant in shoot fresh mass at constant zero; 150; 300 and 450 NPK with the variation in the amount of nitrogen top dressing, at seven weeks after planting. There was an increase in shoot fresh mass when there was no application of nitrogen top dressing and 150; 300 and 450 NPK was added. A significant increase in shoot fresh mass was observed at constant 150 N when there was an addition of 150; 300 and 450 NPK. However, an increase in shoot fresh mass at 300 N was influenced by the application of 300 and 450 NPK.

4.6.3 Shoot fresh mass as influenced by the interaction of season and fertilizer

At five weeks after planting, plants grown either without fertilizer or with different amounts and combinations of NPK basal and nitrogen top dressing fertilizer

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treatments had significantly heavier shoot fresh mass in the warm than in the cold season (Table 4.6a).

Plants grown with the application of 300 N; 150 NPK and 150 N; and 300 NPK produced significantly heavier fresh shoots in the warm than in the cold season, at six weeks after planting. However, a combination of 300 NPK and 150 N resulted in plants with higher shoot fresh mass only in cold season. At seven weeks after planting, seasonal variation did not affect shoot fresh mass of either untreated or fertilizer-treated plants

4.6.4 Shoot dry mass response to different fertilizer treatments in the warm season

Insignificant differences were recorded in the absence of NPK basal fertilizer and a variation in nitrogen top dressing, at five weeks after planting (Table 4.6b). There was an increase in shoot dry mass at 150 NPK when zero and 150 N was applied. At constant 300 NPK, shoot dry mass increased when there was an addition of 150 and 300 N. However, shoot dry mass increased at constant 450 NPK when there was an absence of nitrogen top dressing. When zero and 150 N was kept constant, an increase in shoot dry mass was only observed when 150 and 450 NPK was applied. The highest amount of shoot dry mass was obtained when 300 N was kept constant and 450 NPK was added.

The highest amount in shoot dry mass was obtained in the absence of NPK basal fertilizer when 300 N was applied, at six weeks after planting. However, there was a significant increase in shoot dry mass when 150 NPK was kept constant and there was zero N application. Significantly much more shoot dry mass was obtained at 300 NPK when 150 N was applied. There was a significant increase in shoot dry mass in the absence of nitrogen top dressing when 150 and 450 NPK was applied. When 150 N was kept constant, there was an increase in shoot dry mass when 150; 300 and 450 NPK was applied. The highest amount in shoot dry mass was recorded when 300 N was kept constant and 450 NPK was applied.

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There was an increase in shoot dry mass in the absence of NPK basal fertilizer when 150 N was applied, at seven weeks after planting. When there was an application of 150 and 450 NPK, the addition of nitrogen top dressing did not cause any significant differences in shoot dry mass. Shoot dry mass also increased when there was constant application of 300 NPK and an addition of nitrogen top dressing. When there was no application of nitrogen top dressing, an increase in shoot dry mass was recorded at the application of 150; 300 and 450 NPK. Shoot dry mass increased significantly when there was a constant application of 150 and 300 N and the addition of 150; 300 and 450 NPK.

4.6.5 Shoot dry mass response to different fertilizer treatments in cold season

In the absence of NPK basal fertilizer, the addition of 150 N resulted in an increase in shoot dry mass at five weeks after planting (Table 4.6b). When 150 NPK was kept constant, and there was an application of zero and 150 N, an increase in shoot dry mass was observed. Shoot dry mass increased significantly at constant application of 300 NPK and 300 N. At constant 450 NPK, any addition in nitrogen top dressing resulted in an increase in shoot dry mass. The highest amount in shoot dry mass was recorded at zero and 150 N when 150 NPK was applied. When 300 N was applied, the addition of 300 NPK resulted in an increase in shoot dry mass.

When there was zero and 450 NPK, any addition in nitrogen top dressing caused a significant increase in shoot dry mass at six weeks after planting. However, when there was a constant application of 150 NPK and nitrogen top dressing varied, no significant differences in shoot dry mass were recorded. But when there was an application of 300 NPK, the absence of nitrogen top dressing caused shoot dry mass to increase. When there was no application of nitrogen top dressing, the highest amount in shoot dry mass was caused by the addition of 300 NPK. The highest amount in shoot dry mass at constant 150 and 300 N was influenced by the application of 300 and 450 NPK basal fertilizer.

At seven weeks after planting, when there was no application of NPK basal fertilizer, the addition of 150 N resulted in a significant increase in shoot dry mass. However, when 150 and 450 NPK was kept constant, the variation in nitrogen top dressing did not cause any significant differences in stem dry weight. When there was 300 NPK,

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any addition of nitrogen top dressing caused an increase in shoot dry mass. When there was no application of nitrogen top dressing, an addition of 150; 300 and 450 NPK resulted in an increase in shoot dry mass. The application of 150 and 300 N resulted in a significant increase in shoot dry mass when there was an addition of 150; 300 and 450 NPK basal fertilizer.

4.6.6 Shoot dry mass as influenced by the interaction of season and fertilizer

At five, six and seven weeks after planting, untreated plants as well as fertilizer treated plants at different levels and combinations had higher shoot dry mass in the warm than in the cold season (Table 4.6b). However, at 5 WAP, differences were not significant in plants treated with only 300 NPK in both warm and cold seasons.

4.6.7 Shoot moisture content response to different fertilizer treatments in the warm season

In the absence of NPK basal fertilizer, the application of 150 and 300 N caused a significant increase in shoot moisture content at five weeks after planting (Table 4.6c). An increase in shoot moisture content was observed when 150 NPK was kept constant and there was an application of 300 N. The constant application of 300 NPK resulted in a significant increase in shoot moisture content when zero and 150 N was added. There was a gradual increase in shoot moisture content when 450 NPK was applied and nitrogen top dressing was added. The increase was from 0 kg ha^{-1} with the least stem moisture; followed by 300 and 150 kg ha^{-1} NPK basal fertilizer with the highest shoot moisture content. The most shoot moisture content was recorded when there was application of 300 NPK with no application of nitrogen top dressing. However, when 150 and 300 N application was constant, an absence of NPK basal fertilizer resulted in the most shoot moisture content.

There was an increase in shoot moisture content in the absence of NPK basal fertilizer when zero and 150 N was applied six weeks after planting. When 150 NPK was kept constant, the application of 150 and 300 N resulted in a significant increase in shoot moisture content. The most shoot moisture content was recorded when there was a constant application of 300 and 450 NPK and an absence of nitrogen top dressing. When there was no application of nitrogen top dressing, the application

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of 300 NPK resulted in the most shoot moisture content. At a constant application of 150 N, the most shoot moisture was influenced by the absence of NPK basal fertilizer. However, when 300 N was kept constant, the application of 150 NPK resulted in the most shoot moisture content.

A significant increase in shoot moisture content was recorded when there was 300 N and no application of NPK basal fertilizer at six weeks after planting. No significant differences in shoot moisture content were recorded at constant 150 and 450 NPK when there was a variation in nitrogen top dressing. At constant 300 NPK basal fertilizer application, there was an increase in shoot moisture content when there was an absence of nitrogen top dressing. The highest amount of shoot moisture content was observed when there was no application of nitrogen top dressing and 450 NPK was added. No significant differences in shoot moisture content were observed when 150 N was constant and NPK fertilizer application varied. The most shoot moisture content was obtained when 300 N was kept constant and there was an absence in NPK fertilizer.

4.6.8 Shoot moisture content response to different fertilizer treatments in cold season

At five weeks after planting, there was an increase in shoot moisture content in the absence of NPK basal fertilizer and when 150 and 300 N were applied (Table 4.6c). An increase in moisture content was observed when 300 NPK was kept constant and 300 N was applied. However, no significant differences in shoot moisture content were recorded when constant 300 and 450 NPK basal fertilizer were applied and nitrogen top dressing varied. An increase in shoot moisture content was recorded when zero and 150 N application was kept constant, and there was an increase in the application of NPK fertilizer. However, shoot moisture content increased significantly at 300 N, when 150 and 450 NPK basal fertilizer was applied.

When there was an application of zero 150 and 450 NPK basal fertilizer, the variation in nitrogen top dressing did not cause any significant differences in shoot moisture content, at six weeks after planting. However, there was a significant increase in shoot moisture content when 300 NPK basal fertilizer was kept constant

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and there was an application of 150 and 300 N. The highest shoot moisture content was recorded when there was a constant application of nitrogen top dressing and an addition of 150 NPK basal fertilizer. Shoot moisture content increased significantly when 150 N was kept constant and 150 and 300 NPK basal fertilizer was applied. The highest shoot moisture content was recorded when 300 N was kept constant and there was an application of 300 NPK basal fertilizer.

A significant increase in shoot moisture content was recorded when there was no application of NPK basal fertilizer but only the application of zero and 300 N at seven weeks after planting. The highest amount in shoot moisture content was obtained when there was a constant application of 150 NPK basal fertilizer and an addition of 150 N. When 300 and 450 NPK basal fertilizer was kept constant, the absence of nitrogen top dressing resulted in plants with the highest shoot moisture content. Also, when there was a constant application of zero and 300 N, the absence of NPK basal fertilizer resulted in plants with the highest shoot moisture content. However, there was a significant increase in shoot moisture content when 150 N application was kept constant, while zero and 150 NPK basal fertilizer was added.

4.6.9 Shoot moisture content as influenced by the interaction of season and fertilizer

At five weeks after planting, untreated plants had significantly high shoot moisture content in the warm season (Table 4.6c). Apparently all plants grown in cold season under different fertilizer treatments had significantly higher moisture content than those grown in the warm season. The exception was recorded in plants treated with only 300 N as well as those with only 300 NPK fertilizer, which had moisture content that did not differ significantly with season. Further, plants that were treated with only 150 NPK basal fertilizer had higher moisture content in the warm than in the cold season. Also, measurements at six and seven weeks after planting showed significantly higher moisture content in untreated and fertilizer treated plants grown in the cold than in the warm season.

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4.7 The effect of fertilizer and season on root fresh mass in *C. argyrosperma*

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) and season on root fresh mass of *C. argyrosperma* were measured at five, six and seven weeks after planting (WAP), during the warm and the cold season.

4.7.1 Root fresh mass response to different fertilizer treatments in the warm season

There was an increase in root fresh mass in the absence of NPK basal fertilizer when 150 N was applied at five weeks after planting (Table 4.7 a). When 150; 300 and 450 NPK fertilizer was constant, the variation in nitrogen top dressing fertilizer did not cause any significant differences in root fresh mass. When zero and 300 N was applied, root fresh mass increased significantly when 150; 300 and 450 NPK basal fertilizer was added. However, when 300 N was kept constant, the addition of 300 and 450 NPK basal fertilizer resulted in an increase in root fresh mass.

At six weeks after planting, no significant differences were observed in root fresh mass when there was an application of zero; 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. The increase in root fresh mass was observed at constant zero and 150 N only when 450 NPK basal fertilizer was added. When 300 N was applied, the addition of 300 and 450 NPK basal fertilizer caused a significant increase in root fresh mass.

In the absence of NPK basal fertilizer, there was an increase in root fresh mass when 150 N was added, at seven weeks after planting. However, when 150; 300 and 450 NPK fertilizer was kept constant, variation in nitrogen top dressing fertilizer did not cause any significant differences in root fresh mass.

Root fresh mass increased significantly at constant zero and 300 N when 300 and 450 NPK basal fertilizer was applied. An increase in root fresh mass at constant application of 150 N was influenced by the addition of zero; 300 and 450 NPK basal fertilizer.

Table 4.7a: Influence of different fertilizer treatments and seasons on root fresh mass (g) of *Cucurbita argyrosperma*

Root fresh mass (g) NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	**150**	**300**	**0**	**150**	**300**
5 WAP	**0**	0.92 ± 0.21 ijk	1.54 ± 0.10 ijk	1.14 ± 0.27 ijk	0.37 ± 0.04 k	0.96 ± 0.10 k	0.74 ± 0.14 k
	150	1.39 ± 0.18 jk	1.59 ± 1.10 fgh	1.66 ± 0.11 efgh	0.72± 0.13 k	0.29 ± 0.16 hijk	0.36 ± 0.13 hij
	300	2.00 ± 0.05 ghij	1.99 ± 0.15 de	2.11 ± 0.15 bc	0.47 ± 0.03 ghi	0.56 ± 0.10 ghij	1.01 ± 0.06 cd
	450	2.35 ± 0.11 de	2.35 ± 0.19 a	2.43 ± 0.17 bc	0.61 ± 0.09 efg	0.93 ± 0.02 ab	0.85 ± 0.17 def
6 WAP	**0**	2.84 ± 0.25 jk	2.53 ± 0.32 fgh	2.79 ± 0.19 hijk	1.59 ± 0.11 k	1.30 ± 0.23 hij	1.33 ± 0.15 ijk
	150	2.97 ± 0.19 fghi	2.97 ± 0.31 efg	2.68 ± 0.63 def	1.39 ± 0.19 hij	1.79 ± 0.18 ghij	0.63 ± 0.09 fghi
	300	3.46 ± 0.22 bcde	3.29 ± 0.20 cde	3.80 ± 0.41 abc	1.88 ± 0.22 efg	1.71 ± 0.20 efg	2.39 ± 0.32 cdef
	450	4.00 ± 0.32 ab	4.60 ± 0.36 ab	4.79 ± 0.27 a	2.70 ± 0.15 cde	3.02 ± 0.36 cde	3.21 ± 0.27 abcd
7 WAP	**0**	5.12 ± 0.32 i	6.54 ± 0.43 bcde	5.21 ± 0.25 hi	3.96 ± 0.15 k	4.96 ± 0.43 ij	3.63 ± 0.25 k
	150	5.69 ± 0.40 efghi	5.38 ± 0.31 ghi	6.16 ± 0.70 defgh	4.11 ± 0.40 jk	3.56 ± 0.20 k	3.51 ± 0.13 k
	300	6.27 ± 0.53 defg	6.61 ± 0.31 bcde	6.69 ± 0.16 bcd	4.99 ± 0.44 ij	5.03 ± 0.31 ij	5.45 ± 0.21 fghi
	450	7.34 ± 0.28 abc	7.49 ± 0.42 ab	8.31 ± 0.43 a	6.43 ± 0.27 cdef	6.25 ± 0.34 defg	7.07 ± 0.28 bcd

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

Table 4.7b: Influence of different fertilizer treatments and seasons on root dry mass (g) of *Cucurbita argyrosperma*

Root dry mass (g)		Nitrogen Top Dressing (kg ha^{-1})					
NPK Basal FT (kg ha^{-1})		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
5 WAP	0	0.27 ± 0.05 ijk	0.28 ± 0.05 ijk	0.27 ± 0.05 ijk	0.04 ± 0.01 k	0.07 ± 0.01 k	0.07 ± 0.00 k
	150	0.25 ± 0.50 jk	0.58 ± 010 fgh	0.63 ± 0.13 efgh	0.07 ± 0.01 k	0.34 ± 0.04 hijk	0.43 ± 0.05 hij
	300	0.55 ± 0.12 ghij	0.93 ± 0.05 de	1.34 ± 0.19 bc	0.56 ± 0.17 ghi	0.55 ± 0.05 ghij	1.07 ± 0.19 cd
	450	0.92 ± 0.21 de	1.66 ± 0.11 a	1.26 ± 0.19 bc	0.73 ± 0.17 efg	1.44 ± 0.04 ab	0.88 ± 0.19 def
6 WAP	0	0.92 ± 0.21 jk	1.54 ± 0.10 fgh	1.14 ± 0.27 hijk	0.73 ± 0.17 k	1.16 ± 0.10 hij	1.07 ± 0.19 ijk
	150	1.39 ± 0.18 fghi	1.59 ± 0.10 efg	1.67 ± 0.11 def	1.15 ± 0.13 hij	1.21 ± 0.10 ghij	1.37 ± 0.07 fghi
	300	2.00 ± 0.05 bcde	1.99 ± 0.15 cde	2.11 ± 0.15 abc	1.62 ± 0.05 efg	1.62 ± 0.15 efg	1.73 ± 0.15 cdef
	450	2.35 ± 0.11 ab	2.36 ± 0.19 ab	2.43 ± 0.17 a	1.97 ± 0.10 cde	1.98 ± 0.19 cde	2.05 ± 0.17 abcd
7 WAP	0	2.82 ± 0.25 efghi	2.54 ± 0.32 fghij	2.79 ± 0.19 fghi	2.43 ± 0.25 ghij	1.87 ± 0.15 j	2.41 ± 0.19 k
	150	2.79± 0.19 cdefg	2.47 ± 1.56 ghij	2.52 ± 0.34 fghij	2.59 ± 0.19 fghij	2.09 ± 0.16 ij	2.14 ± 0.34 hij
	300	2.62 ± 0.45 fghij	3.29± 0.20 cdef	2.80 ± 0.22 fghi	2.53 ± 0.35 fghij	2.91 ± 0.20 defgh	2.42 ± 0.22 ghij
	450	3.67 ± 0.46 bcd	3.77 ± 0.47 bc	4.79 ± 0.27 a	3.61 ± 0.32 bcde	3.69 ± 0.36 defg	4.41 ± 0.27 ab

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

Table 4.7c: Influence of different fertilizer treatments and seasons on root moisture content (%) of *Cucurbita argyrosperma*

Moisture content (%) NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
5	0	74.72 ± 1.88 e	81.44 ± 3.09 cde	75.59 ± 4.91 de	88.85 ± 1.65 a	92.27 ± 1.69 a	88.83 ± 1.46 a
WAP	150	81.61 ± 2.58 bcd	66.09 ± 4.90 f	62.71 ± 2.35 f	89.01 ± 2.31 a	85.70 ± 0.67 ab	87.20 ± 0.36 ab
	300	62.01 ± 2.77 f	52.77 ± 1.56 fg	50.49 ± 3.20 gh	87.70 ± 0.86 ab	87.02 ± 2.15 ab	35.50 ± 0.48 j
	450	59.70 ± 2.78 f	38.42 ± 1.75 ij	35.11 ± 3.42 j	44.87 ± 0.44 hi	51.03 ± 1.13 fgh	52.98 ± 1.16 f
6	0	73.29 ± 0.95 c	44.32 ± 0.34 ef	68.93 ± 2.05 bc	60.98 ± 3.57 d	74.75 ± 5.25 ab	62.32 ± 0.52 cd
WAP	150	61.23 ± 2.01 e	59.41 ± 1.37 d	33.71 ± 0.66 hi	40.52 ± 3.72 fgh	44.29 ± 3.59 ef	80.73 ± 2.45 a
	300	43.67 ± 1.73 efg	44.36 ± 2.24 ef	50.13 ± 2.11 e	43.46 ± 1.80 efg	36.62 ± 0.22 ghi	39.41 ± 3.16 fgh
	450	45.63 ± 2.19 ef	42.09 ± 1.51 fg	41.62 ± 1.03 fg	30.49 ± 1.65 i	38.77 ± 3.54 fgh	41.38 ± 5.60 fg
7	0	47.79 ± 2.60 bcdef	57.85 ± 3.25 ab	46.51 ± 2.49 cdef	49.10 ± 1.77 bcdef	60.32 ± 5.59 a	33.29 ± 3.71 hij
WAP	150	49.70 ± 2.19 bcdef	47.09 ± 1.42 cdef	53.99 ± 1.24 abc	35.10 ± 5.53 ghij	40.52 ± 4.93 fghi	53.56 ± 7.25 abcd
	300	52.85 ± 0.63 abcd	50.48 ± 1.34 abcdef	52.52 ± 21.64 abcde	49.21 ± 5.73 bcdef	40.43 ± 6.87 fghi	55.43 ± 4.05 abc
	450	41.80 ± 2.98 fghi	45.41 ± 2.63 cdef	42.27 ± 1.74 efgh	43.71 ± 1.94 defg	28.26 ± 2.43 j	31.81 ± 2.08 ij

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

4.7.2 Root fresh mass response to different fertilizer treatments in cold season

When there was zero and 450 NPK fertilizer, the addition of 150 N resulted in an increase in root fresh mass at five weeks after planting (Table 4.7a). When 150 NPK basal fertilizer was applied, root fresh mass increased significantly in the absence of nitrogen top dressing. However, when there was an application of 300 NPK basal fertilizer, the addition of 300 N resulted in an increase in root fresh mass. An increase in root fresh mass was observed in the absence of nitrogen top dressing but only an addition of 150 NPK basal fertilizer. The application of 150 N resulted in a significant increase in root fresh mass when zero and 450 NPK basal fertilizer were applied. Root fresh mass increased when 300 N was kept constant and zero; and 300 and 450 NPK basal fertilizer was added.

At six weeks after planting when zero and 450 NPK basal fertilizer was applied and there was a variation in nitrogen top dressing, no significant differences in root fresh mass were observed. Root fresh mass increased significantly when 150 NPK basal fertilizer was kept constant and zero and 150 N was applied. The highest amount in root fresh mass at constant zero; 150 and 300 N application was recorded when 450 NPK basal fertilizer was added.

Root fresh mass increased in the absence of NPK basal fertilizer when 150 N was applied at seven weeks after plantng. However, no significant differences in root fresh mass were obtained when there was a variation in nitrogen top dressing. At constant zero; 150 and 300 N, the highest amount in root fresh mass was recorded when 450 NPK basal fertilizer was applied.

4.7.3 Root fresh mass as influenced the interaction effect of season and fertilizer

At five weeks after planting, the fresh mass of roots from plants treated with 300; 450 NPK and 150 N was higher in the warm than in the cold season (Table 4.7a). Insignificant differences were recorded in both warm and cold seasons when zero, 150 and 300 NPK basal fertilizer was kept constant and there was a variation in nitrogen top dressing, at six weeks after planting. However, a significantly high

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amount of root fresh mass was obtained in the warm season from plants grown with only 450 NPK and with a combination of 450 NPK basal fertilizer and 150 N application.

At seven weeks after planting, differences were insignificant in root fresh mass of plants grown under warm and cold seasons in different amounts and combinations of NPK basal and nitrogen top dressing fertilizer treatment.

4.7.4 Root dry mass response to different fertilizer treatments in the warm season

In the absence of NPK basal fertilizer and a variation in nitrogen top dressing, no significant differences in root dry mass were recorded at five weeks after planting (Table 4.7b). An increase in root dry mass was observed when 150 N was kept constant and 300 NPK basal fertilizer was applied. When 300 NPK basal fertilizer was kept constant, the application of 150 and 300 N caused an increase in root dry mass. However, when 450 NPK basal fertilizer was applied, the addition of 150 N caused an increase in root dry mass. An increase in root dry mass was observed in the absence of nitrogen top dressing only when 450 NPK basal fertilizer was applied. When there was a constant application of 150 N, the addition of 300 and 450 NPK basal fertilizer resulted in significantly much more root dry mass. Root dry weight increased at constant 300 N when there was an increase in the application of NPK basal fertilizer.

An increase in root dry mass in the absence of NPK basal fertilizer was recorded when 150 N was applied, at six weeks after planting. However, no significant differences in root dry mass were observed when there was a constant application of 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. The highest amount in root dry mass at constant zero and 150 N was obtained when 300 and 450 NPK basal fertilizer was applied. An increase in root dry mass was observed when 300 N was kept constant and 450 NPK basal fertilizer was added.

There were no significant differences recorded when there was an application of zero, 150 and 300 NPK basal fertilizer and a variation in nitrogen top dressing at seven weeks after planting. However, there was a significant increase in root dry

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mass at constant application of 450 NPK basal fertilizer when 300 N was added. At constant 150 and 300 N, the addition of 450 NPK basal fertilizer resulted a significant increase in root dry mass.

4.7.5 Root dry mass response to different fertilizer treatments in cold season

In the absence of NPK basal fertilizer and a variation in nitrogen top dressing, no significant differences were recorded in root dry mass at five weeks after planting (Table 4.7b). At constant application of 150 NPK basal fertilizer, any addition in nitrogen top dressing influenced an increase in root dry mass. When 300 NPK basal fertilizer was kept constant, the addition of 300 N resulted in a significant increase in root dry mass. Root dry mass increased significantly at the application of 450 NPK basal fertilizer when 150 N was added. An increase in root dry mass was obtained in the absence of nitrogen top dressing when 300 and 450 NPK basal fertilizer was applied. When 150 N was constant, the addition of 150; 300 and 450 NPK basal fertilizer resulted in a significant increase in root dry mass. Root dry mass increased at 300 N when 150; 300 and 400 NPK basal fertilizer was added.

There was an increase in root dry mass in the absence if NPK basal fertilizer when 150 N was applied at six weeks after planting. However, when there was an application of 150; 300 and 450 NPK basal fertilizer, the variation in nitrogen top dressing did not cause any significant differences in root dry mass. An increase in root dry mass at zero and 150 N was influenced by an addition of 300 and 450 NPK basal fertilizer. Root dry mass increased significantly when 300 N was kept constant at and 450 NPK basal fertilizer was added.

When there was an application of zero; 150 and 300 NPK basal fertilizer, the variation in nitrogen top dressing did not cause any significant variation in root dry mass at seven weeks after planting. However, an increase in root dry mass was observed when 450 NPK basal fertilizer was constant and 300 N was applied. At constant zero and 150 N application, root dry mass increased significantly when 300 and 450 NPK basal fertilizer was added. When 300 N was kept constant, an increase in root dry mass was only recorded when 450 NPK basal fertilizer was applied.

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4.7.6 Root dry mass as influenced by the interaction of season and fertilizer

At five weeks after planting, no significant differences in shoot dry mass were recorded from all plants grown in the warm and cold seasons under different fertilizer treatments (Table 4.7b). However, a combination of 300 NPK and 150 N as well as a combination of 450 NPK and 300 N resulted in more root dry mass in the warm season.

Insignificant differences were recorded in shoot dry mass from all plants grown in the warm and cold seasons under different fertilizer treatments at six weeks after planting. However, significantly more root dry mass was recorded in the warm season from plants grown with only 450 NPK and from plants grown with a combination of 450 NPK and 300 N.

At seven weeks after planting, insignificant differences in shoot dry mass were recorded from all plants grown in the warm and cold seasons under different fertilizer treatments. However, plants grown with only 300 N application and plants grown with a combination of 450 NPK and 150 N application resulted in significantly high amount of root dry mass in the warm season.

4.7.7 Root moisture content response to different fertilizer treatments in the warm season

No significant differences in root moisture content were recorded when there was no application in NPK basal fertilizer and a variation in nitrogen top dressing, at five weeks after planting (Table 4.7c). An increase in root moisture content was recorded in the absence of nitrogen top dressing when 150 NPK basal fertilizer was kept constant. Also, much more root moisture content was recorded in the absence of nitrogen top dressing at constant 300 NPK basal fertilizer application. When there was 450 NPK basal fertilizer, the absence of nitrogen top dressing application resulted in more root moisture content. When there was no application of nitrogen top dressing, the addition of 150 NPK basal fertilizer resulted in plants with the highest root moisture content. The highest root moisture content was recorded when 150 and 300 N was kept constant and there was an absence of NPK basal fertilizer.

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An increase in root moisture content was recorded in the absence of NPK basal fertilizer when zero and 300 N was applied, at six weeks after planting. Much more root moisture content was recorded at constant application of 150 NPK basal fertilizer and when 150 N was added. No significant differences in root moisture content were recorded when 300 and 450 NPK basal fertilizer was kept constant and there was a variation in nitrogen top dressing. The highest root moisture content was recorded in the absence of nitrogen top dressing when there was no application of NPK basal fertilizer. A significant increase in root moisture content was recorded when 150 N was kept constant and 150 NPK basal fertilizer was added. The highest root moisture content was obtained when 300 N was added and there was an absence in NPK basal fertilizer.

Significantly more root moisture content was recorded in the absence of NPK basal fertilizer (zero NPK) when 150 N was applied, at seven weeks after planting. No significant differences were recorded when 150; 300 and 450 NPK basal fertilizer was kept constant and nitrogen top dressing varied. Significantly more root moisture content was obtained in plants grown in the absence of nitrogen top dressing but only an application of 300 NPK basal fertilizer. The highest root moisture content was recorded when 150 nitrogen top dressing was kept constant and there was an absence of NPK basal fertilizer. When there was a constant application of 300 N, the addition of 150 NPK resulted in plants with the highest root moisture content.

4.7.8 Root moisture content response to different fertilizer treatments in cold season

At five weeks after planting, no significant differences in root moisture content were recorded when zero and 150 NPK basal fertilizer was kept constant, and nitrogen top dressing varied (Table 4.7c). Root moisture content increased significantly when 300 NPK basal fertilizer was kept constant and, zero and 150 N was applied. The highest amount of root moisture content was recorded at constant application of 450 NPK basal fertilizer and addition of 300 N. An increase in root moisture content was recorded when zero and 150 N was kept constant, and zero; 150 and 300 NPK basal fertilizer was applied. However, when 300 N was kept constant, the application of zero and 150 NPK resulted in an increase in root moisture content.

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An increase in root moisture content was recorded when there was an absence of NPK basal fertilizer and an application of 150 N at six weeks after planting. Also, a significant increase in root moisture content was obtained from plants grown when 150 NPK basal fertilizer was kept constant and 300 N was applied. No significant differences in root moisture content were recorded when 300 NPK basal fertilizer was applied and nitrogen top dressing varied. There was a significant increase in root moisture content in plants grown when the application of 450 NPK was kept constant and there was an addition of 150 and 300 N. Significantly much more root moisture content was recorded when zero and 150 N was kept constant in the absence of NPK basal fertilizer. An increase in root moisture content was recorded when 300 N was constant and, zero and 150 NPK basal fertilizer was added.

At seven weeks after planting, an increase in root moisture content was recorded when there was no NPK basal fertilizer but only 150 N application. The highest root moisture content was recorded when 150 and 300 NPK basal fertilizer was kept constant and there was an application of 300 N. There was a significant increase in root moisture content when there was a constant application of 450 NPK basal fertilizer and an absence of nitrogen top dressing. The most root moisture content was recorded when there was no application of nitrogen top dressing but only zero and 300 NPK basal fertilizer. When 150 N was kept constant, there was a significant increase in root moisture content when there was an absence of NPK basal fertilizer. However, root moisture content increased significantly when there was a constant application of 300 N and an addition of 150 and 300 NPK basal fertilizer.

4.7.9 Root moisture content as influenced by the interaction of season and fertilizer

All plants grown in cold season under different fertilizer treatments had significantly higher root moisture content than those grown in the warm season, at five weeks after planting (Table 4.7c). The exception was recorded in plants which had an application of NPK basal fertilizer and nitrogen top dressing at 300 kg ha^{-1} each as well as from plants treated with only 450 NPK basal fertilizer.

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High root moisture content was recorded in plants which were not treated with any fertilizer treatment in the warm than in the cold season, at six weeks after planting. Plants grown with only 150 N obtained more root moisture content in cold season. Significantly high amount of root moisture content was recorded from plants grown in the warm season when both NPK basal fertilizer and nitrogen top dressing was 150 kg ha^{-1} each. A combination of 150 NPK basal fertilizer and 300 N application resulted in high root moisture content in plants grown in the cold season. Significantly high root moisture content was recorded only in the cold season at constant 300 NPK basal fertilizer, when 150 and 300 N was applied. However, plants grown with only 450 NPK basal fertilizer obtained significantly more root moisture content in the warm than in the cold season.

At seven weeks after planting, significantly high root moisture content was recorded from treated plants grown in the warm than in the cold season.

4.8 The effect of fertilizer treatments and season on the number of flowers in *C. argyrosperma*

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) and season on the number of pistillate and staminate flowers in *C. argyrosperma* was recorded at five, six and seven weeks after planting (WAP), during both the warm and cold seasons.

4.8.1 Staminate flower response to different fertilizer treatments in the warm season

When there was no application of NPK basal fertilizer and a variation in nitrogen top dressing, there were no significant differences in the number of staminate flowers, at five weeks after planting (Table 4.8). Differences were insignificant in the number of staminate flowers recorded when zero; 150 and 300 N was kept constant and an increase in NPK basal fertilizer.

There were no significant differences observed in the number of staminate flowers when there was an application of zero and 300 NPK and a variation in nitrogen top dressing, at six weeks after planting. However, the number of staminate flowers significantly increased when 150 NPK basal fertilizer was kept constant and 150 N was added. The number of staminate flowers also increased when there was a constant application of 450 NPK basal fertilizer and an absence of nitrogen top dressing. When there was no application of nitrogen top dressing but only 450 NPK basal fertilizer, the number of staminate flowers increased significantly. When 150 N was constant, the addition of 150, 300 and 450 NPK basal fertilizer resulted in an increase in the number of staminate flowers. However, no significant differences were recorded when 300 N was applied and NPK basal fertilizer was added.

There were no significant differences observed in staminate flowers when there was no application of NPK basal fertilizer and a variation in nitrogen top dressing, at seven weeks after planting. The increase in the number of staminate flowers at constant 150 NPK basal fertilizer application was influenced by the addition of zero and 300 N.

Table 4.8: Influence of different fertilizer treatments and seasons on the number of staminate flowers of *Cucurbita argyrosperma*

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			**Cold Season (16° - 25°)**		
		0	**150**	**300**	**0**	**150**	**300**
5	**0**	5.67 ± 0.89 cdefg	4.00 ± 0.58 g	5.00 ± 0.58 efg	6.67 ± 0.33 abcde	7.33 ± 0.88 ab	7.00 ± 0.58 abc
WAP	**150**	5.67 ± 0.33 cdefg	4.67 ± 0.33 fg	6.00 ± 0.58 bcdef	6.33 ± 0.33 bcdef	6.33 ± 0.67 bcdef	7.00 ± 0.58 abc
	300	5.33 ± 0.88 defg	5.00 ± 0.58 efg	5.67 ± 0.67 cdefg	7.33 ± 0.33 ab	7.33 ± 0.88 ab	7.00 ± 1.15 abc
	450	5.00 ± 0.58 efg	4.67 ± 0.33 fg	6.00 ± 1.00 bcdef	7.00 ± 0.58 abc	8.33 ± 0.67 a	7.67 ± 0.67 a
6	**0**	11.00 ± 0.58 ghi	9.00 ± 0.58 i	10.33 ± 1.45 fghi	14.00 ± 1.15 abcdef	14.00 ± 1.15 abcdef	10.33 ± 1.45 hi
WAP	**150**	12.67 ± 0.88 defgh	16.57 ± 0.67 ab	13.67 ± 1.20 abcdefg	13.33 ± 0.33 bcdefg	16.00 ± 0.58 ab	14.67 ± 0.88 abcde
	300	13.67 ± 1.20 bcdefg	12.67 ± 1.45 defgh	13.67 ± 1.20 abcdefg	16.00 ± 0.58 ab	15.33 ± 0.88 abcd	16.00 ± 1.15 ab
	450	16.00 ± 0.58 ab	13.00 ± 0.58 cdefgh	12.33 ± 1.45 efgh	16.00 ± 0.58 ab	15.67 ± 1.20 abc	16.33 ± 0.88 a
7	**0**	7.00 ± 0.58 ghi	7.33 ± 1.20 ghi	7.33 ± 0.33 ghi	6.00 ± 0.00 i	6.00 ± 0.58 i	7.00 ± 0.00 ghi
WAP	**150**	10.67 ± 0.33 cde	9.00 ± 0.00 efg	11.00 ± 0.58 cde	6.33 ± 0.88 hi	8.00 ± 0.58 fghi	8.67 ± 0.88 efgh
	300	13.67 ± 0.33 ab	16.00 ± 0.58 a	12.67 ± 0.33 bc	9.00 ± 0.58 efg	11.67 ± 2.60 bcd	9.00 ± 0.58 efg
	450	15.67 ± 0.33 a	13.67 ± 0.33 ab	13.00 ± 0.58 bc	10.00 ± 1.15 def	11.00 ± 1.15 cde	11.00 ± 1.15 cde

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.8: Influence of different fertilizer treatments and seasons on the number of pistillate flowers of *Cucurbita argyrosperma* (Continued)

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
5 WAP	0	1.33 ± 0.33 b	1.67 ± 0.33 ab	2.00 ± 0.00 ab	1.33 ± 0.67 b	2.00 ± 0.58 ab	1.33 ± 0.67 b
	150	2.33 ± 0.33 ab	2.00 ± 0.00 ab	3.00 ± 0.58 a	1.33 ± 0.33 b	1.67 ± 0.33 ab	1.67 ± 0.88 ab
	300	2.00 ± 0.58 ab	2.00 ± 0.00 ab	3.00 ± 0.58 a	2.00 ± 0.58 ab	1.67 ± 0.33 ab	1.33 ± 0.67 b
	450	2.33 ± 0.33 ab	3.00 ± 0.58 a	3.00 ± 0.58 a	2.33 ± 0.33 ab	2.00 ± 1.00 ab	2.33 ± 0.33 ab
6 WAP	0	4.00 ± 0.58 fg	3.67 ± 0.33 g	6.00 ± 0.00 cdef	6.33 ± 0.88 cde	6.00 ± 0.58 cdef	5.67 ± 0.88 defg
	150	6.00 ± 1.00 cdef	6.67 ± 0.67 cde	6.33 ± 0.88 cde	6.00 ± 1.00 cdef	4.67 ± 0.33 efg	5.00 ± 0.00 efg
	300	7.67 ± 0.33 cd	6.00 ± 0.00 cdef	9.33 ± 1.45 abc	6.67 ± 0.88 cde	6.67 ± 0.67 cde	7.67 ± 0.67 cd
	450	10.33 ± 1.45 a	7.67 ± 0.33 cd	8.00 ± 0.58 bcd	10.00 ± 1.73 ab	7.67 ± 0.33 cd	8.00 ± 0.58 bcd
7 WAP	0	3.67 ± 0.67 gh	4.67 ± 1.20 fg	5.00 ± 0.58 fg	3.00 ± 0.00 h	4.00 ± 1.00 gh	4.67 ± 0.67 fg
	150	5.00 ± 0.58 fg	6.00 ± 0.58 ef	6.67 ± 0.33 de	4.67 ± 0.67 fg	4.67 ± 0.33 fg	7.00 ± 0.58 cde
	300	8.00 ± 0.58 abcd	8.67 ± 0.33 ab	8.67 ± 0.33 ab	7.33 ± 0.33 bcde	7.67 ± 0.33 abcd	7.67 ± 0.88 abcd
	450	8.67 ± 0.33 ab	9.00 ± 0.58 a	8.67 ± 0.33 ab	8.67 ± 0.33 ab	8.33 ± 0.33 abc	9.00 ± 0.58 a

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

The number of staminate flowers increased significantly when 300 NPK basal fertilizer was kept constant and 150 N was applied. There was an increase in the number of staminate flowers when 450 NPK basal fertilizer was applied in the absence of nitrogen top dressing. A gradual increase in the number of staminate flowers was observed in the absence of nitrogen top dressing when NPK basal fertilizer was increased. An increase of 150 NPK basal fertilizer had the least staminate flowers, followed by 300 NPK and 450 NPK with the highest number of staminate flowers. The number of staminate flowers increased at constant 150 and 300 N when 150; 300 and 450 NPK basal fertilizer was added.

4.8.2 Staminate flower response to different fertilizer treatments in cold season

NPK basal fertilizer application and nitrogen top dressing did not result in significant differences (Table 4.8). No significant differences were recorded when there was a constant application of zero and 300 N and an increase in the addition of NPK basal fertilizer. However, there were more staminate flowers at constant 150 N when 450 NPK basal fertilizer was added compared to when 150 NPK basal fertilizer was added.

There was an increase in the number of staminate flowers in the absence of NPK basal fertilizer and an addition of 300 N at six weeks after planting. However, no significant differences were observed in the number of staminate flowers when there was an application of 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. A decrease in the number of staminate flowers was observed when there was no application of nitrogen top dressing with addition of 150 NPK basal fertilizer. When there was an application of 150 N, no significant differences were observed. More staminate flowers were observed when there was an application of 300 N and the addition of 450 NPK basal fertilizer.

The number of staminate flowers significantly increased when there was an application of zero and 150 NPK and an addition of 300 N at seven weeks after planting. However, no significant differences were observed when there was an application of 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. The number of staminate flowers increased when there was zero and 300

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N application and the addition of 450 NPK basal fertilizer. More staminate flowers were observed when there was an application of 150 N and the addition of both 300 and 450 NPK basal fertilizer.

4.8.3 Influence of the interaction effect of season and fertilizer season on staminate flowers

All plants grown in the cold season under different fertilizer treatments had significantly numerous staminate flowers than those grown in the warm season, at five weeks after planting (Table 4.8). The exception was recorded in plants untreated as well as those with a combination and variation of 150 NPK fertilizer and plants grown with both NPK fertilizer and nitrogen top dressing at 300 kg ha^{-1} each.

At six weeks after planting insignificant differences were recorded in both the warm and cold seasons from plants grown with any combination and variation of fertilizer. However, the warm season resulted in more staminate flowers from untreated plants, plants grown with only 150 N as well as plants grown with a combination of 450 NPK and 300 N.

All plants grown in the warm season under different fertilizer treatments had significantly numerous staminate flowers than those grown in the cold season at seven weeks after planting. The exception was recorded in plants grown with no application of NPK basal fertilizer, plants grown with both application of NPK basal fertilizer and nitrogen top dressing at 150 kg ha^{-1} each, plants grown with a combination of 300 NPK and 150 kg N and plants grown with a combination of 450 NPK and 300 N.

4.8.4 Pistillate flower response to different fertilizer treatments in the warm season

There were no significant differences observed in the number of pistillate flowers when there was an application of zero; 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing, at five weeks after planting (Table 4.8). When there was an application of zero and 300 N, increase in NPK basal fertilizer did not cause any significant differences in the number of pistillate flowers. A significant

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increase in the number of pistillate flowers was observed at constant 150 N only when 450 NPK basal fertilizer was added.

When there was a constant application of zero and 300 NPK basal fertilizer, the addition of 300 N caused an increase in the number of pistillate flowers, at six weeks after planting. However, no significant differences were observed when 150 NPK basal fertilizer was kept constant and there was a variation in nitrogen top dressing. More pistillate flowers wererecorded at the application of 450 NPK basal fertilizer in the absence of nitrogen top dressing. The highest number of pistillate flowers was observed when zero and 150 N was kept constant and 450 NPK basal fertilizer was applied. However, the increase in the number of pistillate flowers at the application of 300 N was influenced by the addition of 300 and 450 NPK basal fertilizer.

At seven weeks after planting, there were no significant differences observed when zero; 150; 300 and 450 NPK basal fertilizer was constant and there was a variation in nitrogen top dressing. An increase in the amount of pistillate flowers following application of zero and 300 N was influenced by the addition of 300 and 450 NPK basal fertilizer. When 300 N was kept constant, the application of 150; 300 and 450 NPK resulted in an increase in the number of pistillate flowers.

4.8.5 Pistillate flower response to different fertilizer treatments in cold season

When there was an application of zero; 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing, there were no significant differences observed in the number of pistillate flowers of *C. argyrosperma,* five weeks after planting (Table 4.8). The same trend was also observed when there was an application of zero; 150 and 300 N and an increase in the addition of NPK basal fertilizer.

There were no significant differences observed when zero; 150; 300 and 450 NPK basal fertilizer was applied and a variation in nitrogen top dressing, at six weeks after planting. The number of pistillate flowers increased significantly when there was an application of zero and 300 N and addition of 450 NPK basal fertilizer. The increase in the number of pistillate flowers was influenced by the application 300 N and the addition of both 300 and 450 NPK basal fertilizer.

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At seven weeks after planting, when there was an application of zero; 150; 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing, there were no significant differences observed in the number of pistillate flowers. When there was zero and 300 N application, the addition of 450 NPK basal fertilizer resulted in an increase in the number of pistillate flowers. However, when there was an application of 150 N, the addition of 300 NPK basal fertilizer caused an increase in the number of pistillate flowers.

4.8.6 Influence of the interaction effect of season and fertilizer season on pistillate flowers

At five and seven weeks after planting, no significant differences in pistillate flowers were recorded in both the warm and cold seasos from plants grown in different amounts and combinations of NPK basal and nitrogen top dressing fertilizer treatment (Table 4.7).

There were no significant differences recorded in both the warm and cold seasons from plants grown with any combination and variation of fertilizer at six weeks after planting. However, the cold season influenced the production of numerous pistillate flowers in the cold than in the warm season from plants which were untreated as well as plants grown with only 150 N application.

4.9 Response of fruits, fruit mass and size to different fertilizer treatments and season

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) application and season on the number of fruits per plant was observed at five, six, seven, eight and twelve (at harvest) weeks after planting (WAP), during both the warm and cold seasons. Fruit mass and size were only determined at harvest.

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4.9.1 Number of fruits per plant in relation to fertilizer treatments in the warm season

When there was no application of NPK basal fertilizer, the addition of 150 N resulted in an increase in the number of *C. argyrosperma* fruits per plot which grew in the warm season, at five weeks after planting (Table 4.9). There was an increase in the number of fruits per plot when there was an application of 150 NPK basal fertilizer and addition of zero and 300 N. The application of 300 NPK basal fertilizer caused an increase in the number of fruits per plot when 150 N was added. However, no significant differences were observed when there was an application of 450 NPK basal fertilizer and a variation in nitrogen top dressing. An increase in the number of fruits per plot when there was an application of zero and 300 kg N was influenced by the addition of 450 NPK basal fertilizer. However, when there was an application of 150 N, the addition of 300 NPK basal fertilizer resulted in an increase in the number of fruits per plot.

There were no significant differences observed when there was an application of zero; 150 and 300 NPK basal fertilizer and a variation in nitrogen top dressing, at six weeks after planting. However, there was a significant increase in the number of fruits per plot when there was an application of 450 NPK basal fertilizer and the addition of 150 N. An increase in the number of fruits per plot was influenced by the application of zero; 150 and 300 N and the addition of 450 NPK basal fertilizer.

The addition of 300 N resulted in a significant increase in the number of fruits per plot when there was an application of zero and 150 NPK basal fertilizer at seven weeks after planting. However, no significant differences were observed when there was an application of 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. There was an increase in the number of fruits per plot when there was an application of zero; 150 and 300 N and the addition of 450 NPK basal fertilizer.

Table 4.9: Fruit number, fruit mass, fruit diameter and fruit length as influenced by different fertilizer application in different seasons

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
Fruit number 5 WAP	0	0.27 ± 0.02 def	0.31 ± 0.02 bcd	0.29 ± 0.00 cde	0.21 ± 0.00 ef	0.23 ± 0.02 ef	0.25 ± 0.00 def
	150	0.38 ± 0.02 b	0.32 ± 0.00 bcd	0.38 ± 0.02 b	0.25 ± 0.04 ef	0.29 ± 0.04 ef	0.23 ± 0.02 ef
	300	0.52 ± 0.02 a	0.58 ± 0.04 a	0.50 ± 0.04 a	0.25 ± 0.04 f	0.23 ± 0.02 ef	0.33 ± 0.04 bcd
	450	0.56 ± 0.02 a	0.56 ± 0.02 a	0.52 ± 0.02 a	0.36 ± 0.07 bc	0.39 ± 0.07 b	0.39 ± 0.07 b
Fruit number 6 WAP	0	0.24 ± 0.06 e	0.25 ± 0.00 e	0.25 ± 0.04 e	0.00 ± 0.00 g	0.00 ± 0.00 g	0.07 ± 0.00 f
	150	0.41 ± 0.02 c	0.34 ± 0.02 d	0.45 ± 0.02 cd	0.00 ± 0.00 g	0.00 ± 0.00 g	0.07 ± 0.00 f
	300	0.54 ± 0.04 b	0.54 ± 0.00 b	0.50 ± 0.00 c	0.00 ± 0.00 g	0.04 ± 0.00 fg	0.00 ± 0.00 g
	450	0.61 ± 0.04 a	0.65 ± 0.04 a	0.59 ± 0.02 b	0.00 ± 0.00 g	0.25 ± 0.00 e	0.25 ± 0.00 e
Fruit number 7 WAP	0	0.32 ± 0.00 f	0.20 ± 0.02 gh	0.38 ± 0.06 e	0.14 ± 0.07 ijk	0.16 ± 0.09 ij	0.06 ± 0.02 kl
	150	0.29 ± 0.04 fg	0.20 ± 0.06 ghi	0.54 ± 0.04 cde	0.07 ± 0.00 kl	0.08 ± 0.04 kl	0.11 ± 0.00 ijk
	300	0.48 ± 0.02 de	0.54 ± 0.34 bcd	0.57 ± 0.00 abc	0.04 ± 0.00 kl	0.09 ± 0.02 jk	0.07 ± 0.00 kl
	450	0.63 ± 0.13 a	0.66 ± 0.09 a	0.65 ± 0.04 a	0.00 ± 0.00 l	0.04 ± 0.00 kl	0.07 ± 0.00 kl

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.9: Fruit number, fruit mass, fruit diameter and fruit length as influenced by different fertilizer application in different seasons (Continued)

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
Fruit number 8 WAP	0	0.20 ± 0.02 f	0.13 ± 0.02 fgh	0.20 ± 0.06 f	0.00 ± 0.00 i	0.00 ± 0.00 i	0.11 ± 0.00 fgh
	150	0.18 ± 0.00 fg	0.15 ± 0.04 fgh	0.61 ± 0.04 d	0.07 ± 0.00 hi	0.08 ± 0.04 ghi	0.15 ± 0.04 fgh
	300	0.46 ± 0.00 e	0.49 ± 0.06 d	0.75 ± 0.04 ab	0.07 ± 0.00 hi	0.21 ± 0.00 f	0.15 ± 0.04 fgh
	450	0.63 ± 0.17 cd	0.84 ± 0.02 a	0.68 ± 0.04 bc	0.14 ± 0.00 fgh	0.18 ± 0.00 fg	0.16 ± 0.02 fgh
Fruit Number (Harvest)	0	0.18 ± 0.00 ef	0.11 ± 0.00 efgh	0.22 ± 0.08 e	0.00 ± 0.00 h	0.00 ± 0.00 h	0.00 ± 0.00 h
	150	0.14 ± 0.00 efg	0.11 ± 0.00 efgh	0.61 ± 0.04 cd	0.04 ± 0.00 h	0.07 ± 0.00 fgh	0.07 ± 0.00 fgh
	300	0.45 ± 0.02 d	0.49 ± 0.06 e	0.77 ± 0.06 a	0.04 ± 0.00 h	0.07 ± 0.00 fgh	0.08 ± 0.04 fgh
	450	0.66 ± 0.20 bc	0.68 ± 0.14 ab	0.72 ± 0.04 ab	0.07 ± 0.00 fgh	0.06 ± 0.02 fgh	0.08 ± 0.04 fgh
Fruit Mass (kg) (Harvest)	0	0.54 ± 0.08 fg	0.82 ± 0.08 de	0.97 ± 0.05 bcd	0.00 ± 0.00 i	0.00 ± 0.00 i	0.00 ± 0.00 i
	150	0.97 ± 0.05 bcd	0.90 ± 0.05 cd	0.89 ± 0.02 cde	0.00 ± 0.00 i	0.43 ± 0.09 g	0.71 ± 0.12 ef
	300	1.10 ± 0.02 b	2.89 ± 1.42 a	1.52 ± 0.08 a	0.00 ± 0.00 i	0.67 ± 0.06 f	0.57 ± 0.14 fg
	450	0.83 ± 0.05 de	1.03 ± 0.05 bc	1.05 ± 0.04 bc	0.63 ± 0.06 f	0.25 ± 0.03 h	0.00 ± 0.00 i

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

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Table 4.9: Fruit number, fruit mass, fruit diameter and fruit length as influenced by different fertilizer application in different seasons (Continued)

NPK Basal FT (kg ha^{-1})		Nitrogen Top Dressing (kg ha^{-1})					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
Fruit Diameter (cm) (Harvest)	0	38.50 ± 1.95 gh	47.25 ± 2.63 cde	47.00 ± 1.15 cde	0.00 ± 0.00 j	0.00 ± 0.00 j	0.00 ± 0.00 j
	150	47.17 ± 0.80 cde	45.92 ± 1.18 ef	46.17 ± 0.48 de	0.00 ± 0.00 j	39.50 ± 1.75 fgh	36.00 ± 1.03 h
	300	50.50 ± 0.77 abc	54.00 ± 1.24 a	51.17 ± 0.76 ab	0.00 ± 0.00 j	39.83 ± 2.07 fg	42.33 ± 2.84 ef
	450	43.92 ± 0.80 de	49.33 ± 0.75 bcd	50.50 ± 0.43 abc	36.67 ± 2.26 gh	32.17 ± 0.65 i	0.00 ± 0.00 j
Fruit Length (cm) (Harvest)	0	8.33 ± 0.57 de	9.25 ± 0.59 cd	9.75 ± 0.31 bc	0.00 ± 0.00 g	0.00 ± 0.00 g	0.00 ± 0.00 g
	150	9.25 ± 0.11 cd	9.08 ± 0.33 cd	8.83 ± 0.31 cde	0.00 ± 0.00 g	9.17 ± 1.01 cd	7.67 ± 0.33 e
	300	9.83 ± 0.56 bc	11.00 ± 0.26 ab	11.33 ± 0.78 a	0.00 ± 0.00 g	8.67 ± 0.21 cde	11.83 ± 1.13 a
	450	9.25 ± 0.42 cd	9.50 ± 0.26 cd	9.75 ± 0.31 bc	9.17 ± 0.31 cd	6.17 ± 0.17 f	0.00 ± 0.00 g

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at p≤ 0.05 according to Duncan's Multiple Range Test.

At eight weeks after planting, there were no significant differences observed when there was no application of NPK basal fertilizer and an increase in nitrogen top dressing. An increase in the number of fruits per plot was observed when there was an addition of 300 N and an application of 150 and 300 NPK basal fertilizer. However, a decrease in the number of fruits per plot was observed when there was no addition of nitrogen top dressing but an application of 450 NPK basal fertilizer. An increase in the number of fruits per plot was caused by the application of zero and 150 N and the addition of 450 NPK basal fertilizer. However, when there was an application of 300 N, the addition of 300 NPK resulted in an increase in the number of fruits per plot.

At harvest, there were no significant differences observed when there was an application of zero and 450 NPK basal fertilizer and a variation in nitrogen top dressing. However, an increase in the number of fruits per plot was observed when there was an addition of 300 N and an application of 150 and 300 NPK basal fertilizer. The application of zero and 150 N caused an increase in the number of fruits per plot when there was an addition of 450 NPK basal fertilizer. An increase in the number of fruits per plot was influenced by the application of 300 N and the addition of 300 and 450 NPK basal fertilizer.

4.9.2 Number of fruits per plant in relation to different fertilizer treatments in the cold season

There were no significant differences observed when there was an application of zero; 150 and 450 NPK basal fertilizer and a variation in nitrogen top dressing in the number of *C. argyrosperma* fruits per plot which grew in the cold season at five weeks after planting (Table 4.9). The number of fruits per plot increased significantly when there was an application of 300 NPK basal fertilizer and addition of 300 N. The application of zero; 150 and 300 N resulted in an increase in the number of fruits per plot when there was an addition of 450 NPK basal fertilizer.

An increase in the number of fruits per plot was influenced by the application of zero and 150 NPK basal fertilizer and the addition of 300 N at six weeks after planting.

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When there was an application of 300 NPK basal fertilizer, the addition of 150 N resulted in an increase in the number of fruits per plot. The application of 450 NPK basal fertilizer and the addition of 150 and 300 N caused an increase in the number of fruits per plot. There were no significant differences observed when there was no application of nitrogen top dressing and an increase in the addition of NPK basal fertilizer. A significant increase in the number of fruits was observed when there was an application of 150 and 300 N and addition of 450 NPK basal fertilizer.

At seven weeks after planting, there were no significant differences observed in the number of fruits per plot when there was an application of 150, 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. However, an increase in the number of fruits per plot was observed when there was an addition of N and no application of NPK basal fertilizer. The number of fruits per plot increased when there was an application zero, 150 N and no application of NPK basal fertilizer. An increase in the number of fruits per plot was observed when there was an application of 300 N and the addition of 150 NPK basal fertilizer.

At eight weeks after planting, the number of fruits per plot increased significantly when there was an addition of 300 N and an application of zero and 150 NPK basal fertilizer. There was an increase in the number of fruits per plot when there was an addition of 150 N and an application of 300 and 450 NPK basal fertilizer. An increase in the number of fruits per plot was influenced by the addition of 450 NPK basal fertilizer when there was no application of nitrogen top dressing. There were more fruits per plot when there was an application of 150 N and the addition of 300 NPK basal fertilizer. When there was an application of 300 N, the addition of 150 and 300 NPK basal fertilizer resulted in an increase in the number of fruits per plot.

At harvest, there were no significant differences observed when there was zero and 450 NPK basal fertilizer and a variation in nitrogen top dressing. An increase in the number of fruits per plot was caused by the application of 150 NPK basal fertilizer and the addition of 150 and 300 N. There was an increase in the number of fruits per plot when there was an addition of 300 N and application of 300 NPK basal fertilizer. When there was no application of nitrogen top dressing, the addition of 450 NPK basal fertilizer resulted in a significant increase in the number of fruits per plot. There was an increase in the number of fruits per plot when there was an application of 150

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N and the addition of 150 and 300 NPK basal fertilizer. An increase in the number of fruits per plot was caused by the addition of 450 NPK basal fertilizer and the application of 300 N.

4.9.3 Number of fruit per plant in relation to the interaction effect of season and fertilizer

At five, six and seven weeks after planting, untreated plants as well as fertilizer treated plants at different levels and combinations had higher shoot dry mass in the warm than in the cold season (Table 4.9). However, at 5 WAP, differences were not significant in untreated plants as well as plants treated with only 300 N.

4.9.4 Fruit mass and size in relation to different fertilizer treatments in the warm season

Fruit mass of *C. argyrosperma* increased significantly when there was no application on NPK basal fertilizer but the addition of 300 N during the warm season (Table 4.9). However, there were no significant differences observed in fruit mass when 150 NPK basal fertilizer was applied and a variation in nitrogen top dressing. An increase in fruit mass was influenced by the application of 300 and 450 NPK basal fertilizer and the addition of both 150 and 300 N. When there was zero; 150 and 300 N application, the addition of 300 NPK basal fertilizer caused an increase in fruit mass.

Fruit diameter of *C. argyrosperma* decreased when there was no application of NPK basal fertilizer and no addition of nitrogen top dressing, during the warm season (Table 4.9). However, there were no significant differences observed when there was an application of 150 and 300 NPK basal fertilizer and an increase in the addition of nitrogen top dressing. An increase in fruit diameter at the application of 450 NPK basal fertilizer was influenced by the addition of 300 N. When there was an application of zero; 150 and 300 N, the addition of 300 NPK basal fertilizer resulted in a significant increase in fruit diameter.

Fruit length of *C. argyrosperma* increased at the application of zero; 300 and 450 NPK basal fertilizer and the addition of 300 N, during the warm season (Table 4.9).

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However, there were no significant differences observed when there was an application of 150 NPK basal fertilizer and a variation in nitrogen top dressing

When there was an application of zero; 150 and 300 N, the addition of 300 NPK basal fertilizer resulted in a significant increase in fruit length.

4.9.5 Fruit mass and size in response to different fertilizer treatments in cold season

Fruit mass of *C. argyrosperma* increased significantly when there was an application of 150 NPK basal fertilizer but the addition of 300 N, during the cold season (Table 4.9). An increase in fruit mass was observed when there was an application of 300 NPK basal fertilizer and the addition of 150 N. The application of 450 NPK basal fertilizer caused an increase in fruit fresh mass when there was no addition of nitrogen top dressing. However, there were no significant differences observed when there was no application of NPK basal fertilizer and an increase in the addition of nitrogen top dressing. Fruit mass increased significantly when there was no application of nitrogen top dressing but an addition of 450 NPK basal fertilizer. An increase in fruit mass was caused by the application of 150 N and the addition of 300 NPK basal fertilizer.

Fruit diameter of *C. argyrosperma* increased significantly when there was an application of 150 and 300 NPK basal fertilizer and an addition of 150 and 300 N, during the cold season (Table 4.9). When there was an application of 450 NPK, fruit diameter increased when there was no addition of nitrogen top dressing. However, there were no significant differences observed when there was no application of NPK basal fertilizer and an increase in the addition of nitrogen top dressing. Fruit diameter increased when there was no application of nitrogen top dressing but an addition of 450 NPK basal fertilizer. When there was an addition of 300 NPK fertilizer, the application of 150 and 300 N resulted in a significant increase in fruit diameter.

Fruit length of *C. argyrosperma* increased significantly when there was an application of 150 NPK basal fertilizer and an addition of 150 N (Table 4.9). There was an increase in fruit length when there was an application of 300 NPK basal fertilizer and an addition of 150 and 300 N. Fruit length of *C. argyrosperma* increased

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significantly when there was an application of 450 NPK basal fertilizer and no addition of nitrogen top dressing. An increase in fruit length was observed when there was no application of nitrogen top dressing but an addition of 450 NPK basal fertilizer. The increase in fruit length was influenced by the addition of 300 NPK basal fertilizer when there was an application of 150 and 300 N.

4.9.6 Fruit mass and size as influenced by the interaction effect of season and fertilizer

Significantly higher fruit mass was recorded from plants grown in the warm than in the cold season in different amounts and combinations of NPK basal and nitrogen top dressing fertilizer treatment (Table 4.9). However, no significant differences were recorded from plants grown with a combination of 150 NPK and 300 N in both the warm and cold seasons.

Different amounts and combinations NPK basal and nitrogen top dressing fertilizer treatment resulted in plants which produced fruits with the largest diameter in the warm season (Table 4.9). However, no significant differences were recorded from plants grown in the warm and cold seasons when both NPK basal fertilizer and nitrogen top dressing were applied at 150 kg ha^{-1} each.

Significantly longer fruits were recorded from plants grown in the warm than in the cold season in different amounts and combinations of NPK basal and nitrogen top dressing fertilizer treatment (Table 4.9). However, no significant differences were recorded from plants grown in the warm and cold seasons when both NPK basal fertilizer and nitrogen top dressing were applied at 150 kg ha^{-1} each and from plants grown with a combination of 150 NPK and 300 N.

4.10 Total seed number, total seed weight, hundred seed mass and seed size in response to different fertilizer treatments and season

The effect of NPK basal fertilizer (NPK), nitrogen top dressing (N) and season on the numbers of seeds per fruit, total seed mass, hundred seed mass and seed size was measured at harvest.

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4.10.1 Number of total seed in response to different fertilizer treatments in the warm season

Differences were not significant in the total number of seed per fruit in the absence as well as application of 300 NPK basal fertilizer, when nitrogen top dressing was varied (Table 4.10a). A significant increase in total seed was recorded when 150 NPK basal fertilizer was kept constant and there was an addition of zero and 300 N. Also, when there was a constant application of 450 NPK basal fertilizer, an addition of 150 and 300 N resulted in a significant increase in total number of seed. However, when zero and 150 N was kept constant, and there was an application of 300 NPK basal fertilizer, the highest number of seeds per fruit was recorded. A significant increase in total seed was recorded when there was an application of 300 N and an addition of 300 and 450 NPK basal fertilizer.

4.10.2 Total number of seed in response to different fertilizer treatments in the cold season

Insignificant differences in total seed were recorded in the absence of NPK with a variation of nitrogen top dressing (Table 4.10a). The highest number of seeds per fruit was recorded at constant application of 150 and 300 NPK basal fertilizer when 150 and 300 N was added. An increase in total number of seeds per fruit was recorded when 450 NPK basal fertilizer was kept constant and there was an addition of zero and 150 N.

Table 4.10a: Total seed number, total seed mass (g), hundred seed mass (g) of *C. argyrosperma* to NPK basal fertilizer and nitrogen top dressing

NPK Basal FT ($kg\ ha^{-1}$)		Nitrogen Top Dressing ($kg\ ha^{-1}$)					
		Warm Season (23° - 33°)			Cold Season (16° - 25°)		
		0	150	300	0	150	300
Total	0	220.71 ± 16.03 cde	191.14 ± 18.22 efg	208.14 ± 28.98 def	0.00 ± 0.00 k	0.00 ± 0.00 k	0.00 ± 0.00 k
Seed	150	251.71 ± 24.55 cd	93.57 ± 6.27 ij	225.14 ± 26.61 cde	0.00 ± 0.00 k	127.14 ± 11.75 hi	214.71 ± 24.03 cde
number	300	426.43 ± 16.08 a	413.14 ± 17.77 a	391.14 ± 28.15 a	0.00 ± 0.00 k	152.43 ± 09.38 gh	251.43 ± 10.69 cd
	450	257.29 ± 11.45 c	343.86 ± 13.54 b	436.71 ± 29.85 a	165.57 ± 19.70 fgh	62.14 ± 6.97 j	0.00 ± 0.00 k
Total	0	98.14 ± 0.34 a	90.43 ± 5.17 bc	91.86 ± 2.29 abc	0.00 ± 0.00 h	0.00 ± 0.00 h	0.00 ± 0.00 h
Seed	150	82.00 ± 5.38 de	71.71 ± 8.17 f	90.57 ± 2.16 bc	0.00 ± 0.00 h	85.31 ± 1.73 cde	91.85 ± 1.20 abc
Mass	300	95.86 ± 0.70 ab	96.43 ± 1.15 ab	95.00 ± 1.05 ab	0.00 ± 0.00 h	78.76 ± 1.35 ef	90.89 ± 1.39 abc
(%)	450	89.43 ± 2.96 bcd	96.86 ± 0.40 ab	90.86 ± 4.17 abc	86.97 ± 1.35 cd	56.83 ± 1.90 g	0.00 ± 0.00 h
Hundred	0	19.41 ± 0.75 a	15.15 ± 0.95 cde	16.96 ± 0.18 b	0.00 ± 0.00 j	0.00 ± 0.00 j	0.00 ± 0.00 j
Seed	150	14.94 ± 0.54 cde	13.52 ± 0.48 fgh	12.85 ± 0.15 ghi	0.00 ± 0.00 j	12.46 ± 0.36 hi	11.86 ± 0.38 i
Mass	300	14.46 ± 0.33 def	13.52 ± 0.17 fgh	15.70 ± 0.30 c	0.00 ± 0.00 j	12.66 ± 0.36 ghi	13.41 ± 0.79 fgh
(g)	450	14.03 ± 0.41 ef	14.08 ± 0.38 ef	14.46 ± 0.58 def	13.66 ± 0.26 fg	15.49 ± 0.28 cd	0.00 ± 0.00 j

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test.

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Table 4.10b: Seed size response of *C. argyrosperma* to NPK basal fertilizer and nitrogen top dressing

NPK Basal FT ($kg\ ha^{-1}$)		Nitrogen Top Dressing ($kg\ ha^{-1}$)					
		Warm Season (23° - 33°)			**Cold Season (16° - 25°)**		
		0	**150**	**300**	**0**	**150**	**300**
Seed Length (mm)	**0**	13.90 ± 0.29 gh	13.20 ± 0.15 jkl	16.51 ± 0.14 b	0.00 ± 0.00 m	0.00 ± 0.00 m	0.00 ± 0.00 m
	150	14.10 ± 0.12 fgh	13.63 ± 0.29 ij	13.82 ± 0.25 hi	0.00 ± 0.00 m	12.72 ± 0.11 l	12.64 ± 0.14 l
	300	14.18 ± 0.20 efg	17.47 ± 0.16 a	15.28 ± 0.17 d	0.00 ± 0.00 m	13.33 ± 0.19 jk	12.91 ± 0.15 l
	450	16.39 ± 0.13 bc	14.29 ± 0.18 def	14.54 ± 0.08 de	12.90 ± 0.07 jkl	12.84 ± 0.12 kl	0.00 ± 0.00 m
Seed Width (mm)	**0**	8.40 ± 0.16 d	7.90 ± 0.21 e	8.95 ± 0.09 c	0.00 ± 0.00 h	0.00 ± 0.00 h	0.00 ± 0.00 h
	150	8.53 ± 0.08 d	8.90 ± 0.11 c	8.27 ± 0.08 d	0.00 ± 0.00 h	7.36 ± 0.06 g	7.53 ± 0.08 fg
	300	8.47 ± 0.08 d	9.81 ± 0.09 a	9.81 ± 0.08 a	0.00 ± 0.00 h	7.69 ± 0.08 ef	7.52 ± 0.08 fg
	450	9.33 ± 0.16 b	8.34 ± 0.17 d	8.38 ± 0.11 d	7.64 ± 0.10 ef	7.78 ± 0.14 ef	0.00 ± 0.00 h
Seed Thickness (mm)	**0**	2.43 ± 0.06 hij	2.43 ± 0.04 hij	2.73 ± 0.04 de	0.00 ± 0.00 l	0.00 ± 0.00 l	0.00 ± 0.00 l
	150	2.66 ± 0.02 ef	2.97 ± 0.09 bc	2.62 ± 0.07 ef	0.00 ± 0.00 l	2.33 ± 0.05 k	2.37 ± 0.04 jk
	300	2.57 ± 0.08 efg	2.83 ± 0.08 cd	3.06 ± 0.05 b	0.00 ± 0.00 l	2.47 ± 0.06 hij	2.37 ± 0.05 jk
	450	2.57 ± 0.05 efg	3.31 ± 0.04 a	3.37 ± 0.05 a	2.38 ± 0.05 ijk	2.47 ± 0.07 hij	0.00 ± 0.00 l

NPK, Nitrogen Phosphorus Potassium fertilizer; FT, Fertilizer treatments; WAP, weeks after planting. Values are mean ± standard error (SE). Mean values followed by different letter(s) within a column and a row differ significantly at $p \leq 0.05$ according to Duncan's Multiple Range Test.

4.10.3 Total seed number as influenced by the interaction effect of season and fertilizer

Fertilizer treated plants and untreated plants at different levels and combinations had significantly high number of seeds per fruit in the warm than in the cold season (Table 4.10a).

4.10.4 Total seed mass in response to different fertilizer treatments in the warm season

When there was no application of NPK basal fertilizer, a gradual increase in seed mass was observed, from 150 N with the lowest; followed by 300 N then zero N with the highest (Table 4.10a). A significant increase in seed mass was recorded when 150 NPK basal fertilizer was kept constant and there was an addition of zero and 300 N. However, there were no significant differences observed when there was an application of 300 and 450 NPK basal fertilizer and a variation in nitrogen top dressing. When there was no application of nitrogen top dressing, the addition of zero NPK basal fertilizer resulted in the highest seed mass. High seed mass was obtained from the application of 150 N when there was an addition of zero; 300 and 450 NPK basal fertilizer. No significant differences were recorded at constant application of 300 N and variation of NPK basal fertilizer.

4.10.5 Total seed mass in response to different fertilizer treatments in the cold season

No significant differences in total seed number were recorded in the absence of NPK when there was variation in nitrogen top dressing (Table 4.10a). An increase in seed mass was observed when 150 and 300 NPK basal fertilizer was kept constant and there was an addition of 150 and 300 N. However, when there was a constant application of 450 NPK basal fertilizer, an addition of zero and 150 N resulted in an increase in seed mass. The seed mass increased significantly when there was no application of nitrogen top dressing but an addition of 450 NPK basal fertilizer. The application of 150 N resulted in an increase in seed mass when there was an

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addition of 150; 300 and 450 NPK basal fertilizer. An increase in seed mass was recorded when 300 N was kept constant and there was an addition of 150 and 300 NPK basal fertilizer.

4.10.6 Total seed mass as influenced by the interaction effect of season and fertilizer

Untreated plants as well as fertilizer treated plants at different levels and combinations had higher seed mass in the warm than in the cold season (Table 4.10a).

4.10.7 Hundred seed mass in response to different fertilizer treatments in the warm season

When the NPK basal fertilizer was not applied and also kept at 150 NPK, the absence of nitrogen top dressing resulted in the heaviest hundred seed mass (Table 4.10a). When there was 300 NPK basal fertilizer, the addition of 300 N resulted in significantly higher hundred seed mass. However, when 450 NPK basal fertilizer was kept constant, the variation in nitrogen top dressing application did not cause any significant differences in the hundred seed mass. When there was an application of zero; 150 and 300 N, the absence of NPK basal fertilizer resulted in the heaviest hundred seed mass.

4.10.8 Hundred seed mass in response to different fertilizer treatments in the cold season

There were no significant differences recorded when there was no application of NPK basal fertilizer and a variation in nitrogen top dressing (Table 4.10a). When 150 and 300 NPK basal fertilizer was kept constant, any addition of nitrogen top dressing resulted in an increase in hundred seed mass. The heaviest hundred seed mass was recorded at 450 NPK basal fertilizer when there was an addition of 150 N. When zero and 150 N was constant, the application of 450 NPK basal fertilizer resulted

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with the highest hundred seed mass. However, when 300 N was kept constant, the addition of 300 NPK basal fertilizer resulted in the heaviest hundred seed mass.

4.10.9 Hundred seed mass as influenced by the interaction effect of season and fertilizer

Apparently, all plants grown in the warm season under different fertilizer treatments had significantly higher hundred seed mass than those grown in the cold season (Table 4.10a). The exception was recorded in plants treated with a combination of 450 NPK basal fertilizer and 150 N, which had higher hundred seed mass in the cold season.

4.10.10 Seed length, width and thickness in response to different fertilizer treatments in the warm season

In the absence of NPK basal fertilizer, the application of 300 N resulted in the longest seeds (Table 4.10b). However, when the application of 150 and 450 NPK basal fertilizer was kept constant, the absence in nitrogen top dressing caused longer seeds. Also, longer seeds were obtained at constant 300 NPK basal fertilizer when 150 N was applied.

Seed width increased with the application of only 300 N (Table 4.10b). Further, a combination of 150 NPK basal fertilizer and 150 N resulted in wider seeds. An increase in seed width was obtained when 300 NPK basal fertilizer application was constant and there was an addition and increase in nitrogen top dressing. The application of only 450 NPK basal fertilizer also resulted in wider seeds. The widest seeds were obtained when both NPK basal fertilizer and nitrogen top dressing were applied at 300 kg ha^{-1} each.

The application of only 300 N resulted in thicker seeds (Table 4.10b). Also, a combination of 150 NPK basal fertilizer and 150 N, resulted in thicker seeds. However, when there was an application of 300 and 450 NPK basal fertilizer, the addition nitrogen top dressing resulted in an increase in seed thickness. An application as well as increase of only NPK basal fertilizer in the presence of

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constant 150 N, resulted in an increase in seed thickness. When there was ab application of 300 N, the addition of 300 and 450 NPK basal fertilizer resulted in thicker seeds.

4.10.11 Seed length, width and thickness in response to different fertilizer treatments in the cold season

Insignificant differences in seed length were recorded in the absence of NPK basal fertilizer with a variation in nitrogen top dressing (Table 4.10b). When 150 and 300 NPK basal fertilizer was kept constant, the addition of nitrogen top dressing resulted in an increase in seed length. However, when 450 NPK basal fertilizer application was constant, the addition of zero and 150 N resulted in an increase in seed length. In the absence of nitrogen top dressing, the application of 450 NPK basal fertilizer resulted in longer seeds.

Insignificant differences in seed width were recorded in the absence of NPK basal fertilizer with a variation in nitrogen top dressing (Table 4.10b). When 150 and 300 NPK basal fertilizer was kept constant, the addition and increase of nitrogen top dressing resulted in an increase in seed width. However, when 450 NPK basal fertilizer application was constant, the addition of zero and 150 N resulted in an increase in seed width. An application of only 450 NPK basal fertilizer resulted in wider seeds. When there was an application of 150 N, the addition of NPK basal fertilizer caused an increase in seed width. Wider seeds were obtained when nitrogen top dressing was kept constant at 300 N and there was an application of 150 and 300 NPK basal fertilizer.

Insignificant differences in seed thickness were recorded in the absence of NPK basal fertilizer with a variation in nitrogen top dressing (Table 4.10b). When 150 and 300 NPK basal fertilizer was kept constant, the addition of nitrogen top dressing resulted in an increase in seed thickness. However, when 450 NPK basal fertilizer application was constant, the addition of zero and 150 N resulted in an increase in seed height. An application of only 450 NPK basal fertilizer resulted in thicker seeds. When 150 N was kept constant, the addition of NPK basal fertilizer caused an increase in seed height. Thicker seeds were obtained when 300 N was kept constant and there was an application of 150 and 300 NPK basal fertilizer.

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4.10.12 Seed length, width and thickness as influenced by the interaction effect of season and fertilizer

All plants grown in the warm season under different fertilizer treatments had significantly longer seeds than those grown in the cold season (Table 4.10b). Both fertilizer treated plants and untreated plants grown in the warm season under different fertilizer treatments had significantly wider seeds than those grown in the cold season. All plants grown in the warm season under different fertilizer treatments had significantly thicker seeds than those grown in the cold season.

4.12 Principal Component Analysis

In this study Principal Component Analysis (PCA) emphasized the variation and also brought about strong patterns among the agronomic traits. Principal Component Analysis (PCA) showed that the four most informative principal components explained 88.97% of the total variation (Table 4.11). The first component accounted for 60.70% of the total variation, and was mainly defined positively by all traits except shoot moisture content which was negative. The second component explained 17.25% of the total variation and was only correlated positively by shoot growth, stem diameter, number of leaves, leaf growth, and shoot fresh mass, shoot dry mass, shoot moisture content, root fresh mass, root dry mass, staminate flowers, pistillate flowers and fruit number per plant.

The third component accounted for 6.01% and was defined positively, by shoot growth, number of leaves; shoot fresh mass, shoot dry mass, root moisture content, staminate flowers, pistillate flowers and fruit mass. The fourth component explained 5% of the total variation and was mainly defined by leaf growth, chlorophyll content, shoot dry mass, and root fresh mass, root dry mass, root moisture content, staminate flowers, fruit per plant, fruit mass, and number of seed per fruit.

4.13 Correlation among agronomic traits

The correlation analysis is one of the striking approaches that can yield adequate evidence on the associations among agronomic traits of *C. argyrosperma*. A correlation value which is $r \geq 0.60$ indicates a strong correlation among the evaluated

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traits. A weak correlation was recorded between stem growth and all agronomic traits (Table 4.12). Shoot moisture content was negatively correlated with all traits. Stem diameter showed a strong positive correlation with number of leaves, leaf growth, shoot fresh mass, shoot dry mass, root fresh mass, root dry mass, staminate flowers and pistillate flowers.

Table 4.11: Vector loading and percentage of variation explained by the first four principal components

Variables	PC1	PC2	PC3	PC4
SG	0.293	0.384	0.723	-0.304
SD	0.693	0.599	-0.006	-0.068
NL	0.831	0.451	0.136	-0.086
LG	0.817	0.283	-0.238	0.213
Chl	0.868	-0.031	-0.037	0.060
SFM	0.678	0.576	0.193	-0.290
SDM	0.915	0.162	0.257	0.071
SMC	-0.808	0.232	-0.217	-0.227
RFM	0.738	0.397	-0.164	0.324
RDM	0.482	0.644	-0.510	0.065
RMC	0.152	-0.593	0.487	0.473
SFl	0.825	0.400	0.048	0.089
PFl	0.690	0.626	0.097	-0.121
FPP	0.780	0.129	-0.016	0.429
FM	0.797	-0.200	0.140	0.196
FD	0.907	-0.395	-0.040	-0.109
FL	0.876	-0.407	-0.001	-0.198
SPF	0.887	-0.186	-0.008	0.219
TSM	0.852	-0.455	-0.070	-0.170
100SM	0.811	-0.483	-0.172	-0.210
SL	0.881	-0.400	-0.118	-0.194
SW	0.883	-0.401	-0.080	-0.205
ST	0.904	-0.340	-0.144	-0.158
Eigenvalue	13.961	3.968	1.383	1.151
Variability (%)	60.699	17.252	6.012	5.005
Cumulative %	60.699	77.951	83.962	88.967

SG – Shoot growth; SD – Stem diameter; NL – Number of leaves; LF – Leaf growth; Chl – Chlorophyll content; SFM – Shoot Fresh Mass; SDM – Shoot Fresh Mass; SMC – Shoot Moisture Content; SFl – Staminate Flowers; PFl – Pistillate flowers; FPP – Fruit per plant; FM – Fruit Mass; FD – Fruit Diameter; FL – Fruit Length; SPF – Seed per fruit; TSM – Total Seed Mass; 100SM – 100 Seed Mass; SL – Seed Length; SW – Seed width; ST – Seed Thickness.

A strong positive correlation was also observed between number of leaves and leaf growth, chlorophyll content, shoot fresh mass, shoot dry mass, root fresh mass,

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staminate flowers, pistillate flowers, number of fruits per plant, number of seeds per fruit and seed thickness. The correlation between leaf growth and chlorophyll content, shoot fresh mass, shoot dry mass, root fresh mass, root dry mass, staminate flowers, pistillate flowers, number of fruits per plant, fruit diameter, number of seeds per fruit and seed thickness was also positive.

Chlorophyll content had a strong positive correlation with most agronomic traits except for shoot growth, stem diameter, shoot fresh mass, shoot moisture content, root dry mass, root moisture content and pistillate flowers. Shoot fresh mass had a strong positive correlation with shoot dry mass, staminate flowers and pistillate flowers. Shoot dry mass had positive correlation with almost all traits except shoot growth, root dry mass and root moisture content. Root fresh mass had a very strong correlation with root dry mass, staminate flowers, pistillate flowers and number of fruits per plant. Root dry mass had a positive correlation only with staminate flowers and pistillate flowers.

A strong positive correlation was observed between staminate flowers and pistillate flowers, number of fruits per plant, fruit mass and number of seeds per fruit. The number of fruits per plant had a strong positive correlation with fruit mass, fruit diameter, number of seeds per plant and seed thickness. Fruit mass, fruit diameter, fruit length, number of seeds per fruit, total seed mass, 100 seed mass and seed width had an extremely strong positive correlation with each other.

4.14 Scatter plot analysis

To intensely determine the interrelationships among agronomic traits of *C. argyrosperma*, scatter plot analysis was performed by matching the eigenvalues of PC1 and PC2 of principal component analysis (PCA) (Figure 4.1). This means that these traits were influenced positively by the use of fertilizer. Almost all traits were positively defined by PC1 except shoot moisture content. However, PC2 was negatively defined by number of seeds per fruit, fruit mass, seed thickness, total seed mass, hundred seed mass and root moisture content. Therefore, these traits can be affected by fertilizer application.

Table 4.12: Correlation coefficient between the agronomic traits of *Cucubita argyrosperma* grown in different fertilizer treatments.

Variables	SG	SD	NL	LG	Chl	SFM	SDM	SMC	RFM	RDM	RMC	SFl	PFl	FPP	FM	FD	FL	SPF	TSM	100SM	SL	SW
SD	0.41																					
NL	0.49	**0.83**																				
LG	0.08	**0.74**	**0.77**																			
Chl	0.27	0.54	**0.71**	**0.67**																		
SFM	0.57	**0.83**	**0.89**	**0.65**	0.48																	
SDM	0.46	**0.72**	**0.88**	**0.76**	**0.80**	**0.76**																
SMC	-0.25	-0.41	-0.59	-0.57	-0.79	-0.35	-0.86															
RFM	0.22	**0.70**	0.69	**0.76**	**0.72**	0.59	**0.72**	-0.59														
RDM	0.07	**0.72**	0.58	**0.65**	0.44	0.55	0.41	-0.17	**0.79**													
RMC	-0.02	-0.23	-0.12	-0.04	0.09	-0.23	0.17	-0.40	0.00	-0.51												
SFl	0.35	**0.75**	**0.89**	**0.74**	**0.66**	**0.78**	**0.82**	-0.54	**0.74**	**0.60**	-0.07											
PFl	0.51	**0.88**	**0.87**	**0.70**	0.50	**0.90**	**0.70**	-0.33	**0.70**	**0.67**	-0.19	**0.83**										
FPP	0.20	0.55	**0.68**	**0.78**	**0.70**	0.45	**0.72**	-0.65	**0.71**	0.46	0.16	**0.76**	0.55									
FM	0.15	0.41	0.54	0.58	**0.64**	0.41	**0.76**	-0.72	0.46	0.20	0.33	**0.68**	0.42	**0.64**								
FD	0.12	0.41	0.58	**0.62**	**0.80**	0.41	**0.75**	-0.79	0.49	0.19	0.30	0.58	0.38	**0.61**	**0.77**							
FL	0.15	0.39	0.55	0.59	**0.74**	0.44	**0.71**	-0.72	0.43	0.15	0.32	0.53	0.39	0.54	**0.73**	**0.98**						
SPF	0.13	0.50	**0.63**	**0.74**	**0.73**	0.43	**0.74**	-0.72	0.59	0.32	0.35	**0.71**	0.49	**0.79**	**0.82**	**0.86**	**0.83**					
TSM	0.08	0.34	0.51	0.55	**0.71**	0.36	**0.65**	-0.71	0.41	0.15	0.32	0.50	0.35	0.55	**0.70**	**0.97**	**0.98**	**0.84**				
100SM	0.03	0.28	0.44	0.50	**0.72**	0.28	**0.60**	-0.70	0.41	0.18	0.23	0.43	0.27	0.48	**0.63**	**0.95**	**0.95**	**0.75**	**0.97**			
SL	0.07	0.38	0.55	0.58	**0.76**	0.40	**0.69**	-0.73	0.45	0.21	0.22	0.57	0.38	0.56	**0.74**	**0.98**	**0.97**	**0.81**	**0.97**	**0.97**		
SW	0.11	0.37	0.56	0.57	**0.77**	0.41	**0.71**	-0.75	0.45	0.20	0.23	0.56	0.38	0.56	**0.73**	**0.98**	**0.97**	**0.79**	**0.97**	**0.97**	1.00	
ST	0.08	0.45	**0.60**	**0.68**	**0.79**	0.44	**0.73**	-0.75	0.50	0.27	0.21	0.57	0.42	**0.60**	**0.71**	**0.98**	**0.96**	**0.81**	**0.96**	**0.95**	**0.98**	**0.98**

SG – Shoot growth; SD – Stem diameter; NL – Number of leaves; LF – Leaf growth; Chl – Chlorophyll content; SFM – Shoot Fresh Mass; SDM – Shoot Fresh Mass; SMC – Shoot Moisture Content; SFl – Staminate Flowers; PFl – Pistillate flowers; FPP –Number of fruits per plant; FM – Fruit Mass; FD – Fruit Diameter; FL – Fruit Length; SPF – Seed per fruit; TSM – Total Seed Mass; 100SM – 100 Seed Mass; SL – Seed Length; SW – Seed width; ST – Seed Thickness.

Both PC1 and PC2 were positively defined by shoot growth, root dry mass, root fresh mass, shoot fresh mass, number of leaves, pistillate flowers, staminate flowers, leaf growth, shoot dry mass and number of fruits per plant. A positive correlation was determined for chlorophyll content, number of seeds per fruit, fruit mass, seed thickness, total seed mass, and hundred seed mass, in only PC1.

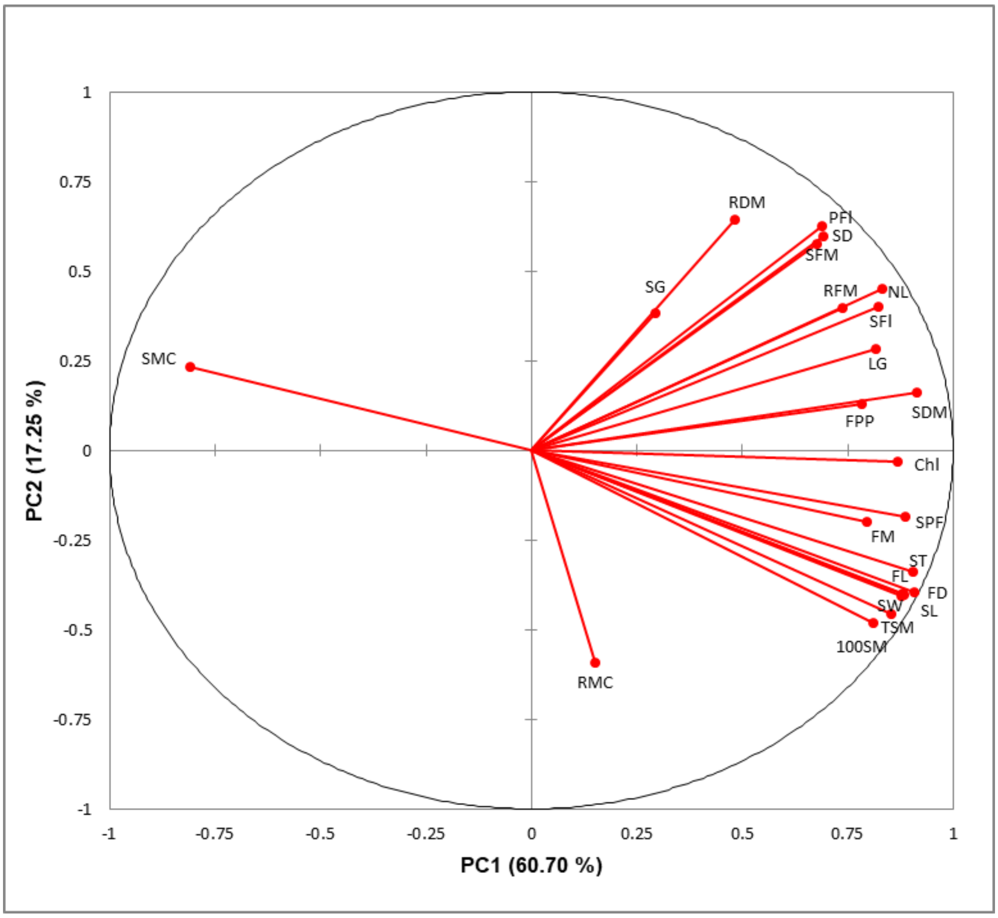

Figure 4.1: Scatter plot based on principal component analysis for agronomic traits of *C. argyrosperma*

SG – Shoot growth; SD – Stem diameter; NL – Number of leaves; LF – Leaf growth; Chl – Chlorophyll content; SFM – Shoot Fresh Mass; SDM – Shoot Fresh Mass; SMC – Shoot Moisture Content; RFM – Root Fresh Mass; RDM – Root Dry Mass; RMC; Root Moisture Content; SFl – Staminate Flowers; PFl – Pistillate flowers; FPP – Fruit per plant; FM – Fruit Mass; FD – Fruit Diameter; FL – Fruit Length; SPF – Seed per fruit; TSM – Total Seed Mass; 100SM – 100 Seed Mass; SL – Seed Length; SW – Seed width; ST – Seed Thickness.

The scatter plot for different fertilizer treatments in the warm and cold seasons with PC1 and PC2 resulted in four distinct groups (Figure 4.2). Fertilizer treatments in Group I had positive correlation for both PC1 and PC2. Group I was formed by both

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300 and 450 kg ha^{-1} NPK basal fertilizer with varying nitrogen top dressing in the warm season. In the cold season, this group was formed by the following combinations: 300 NPK 150 N; 450 NPK 0 N; and 450 NPK 150 N. Therefore the application of these fertilizer combinations in warm and cold season yielded plants with high growth.

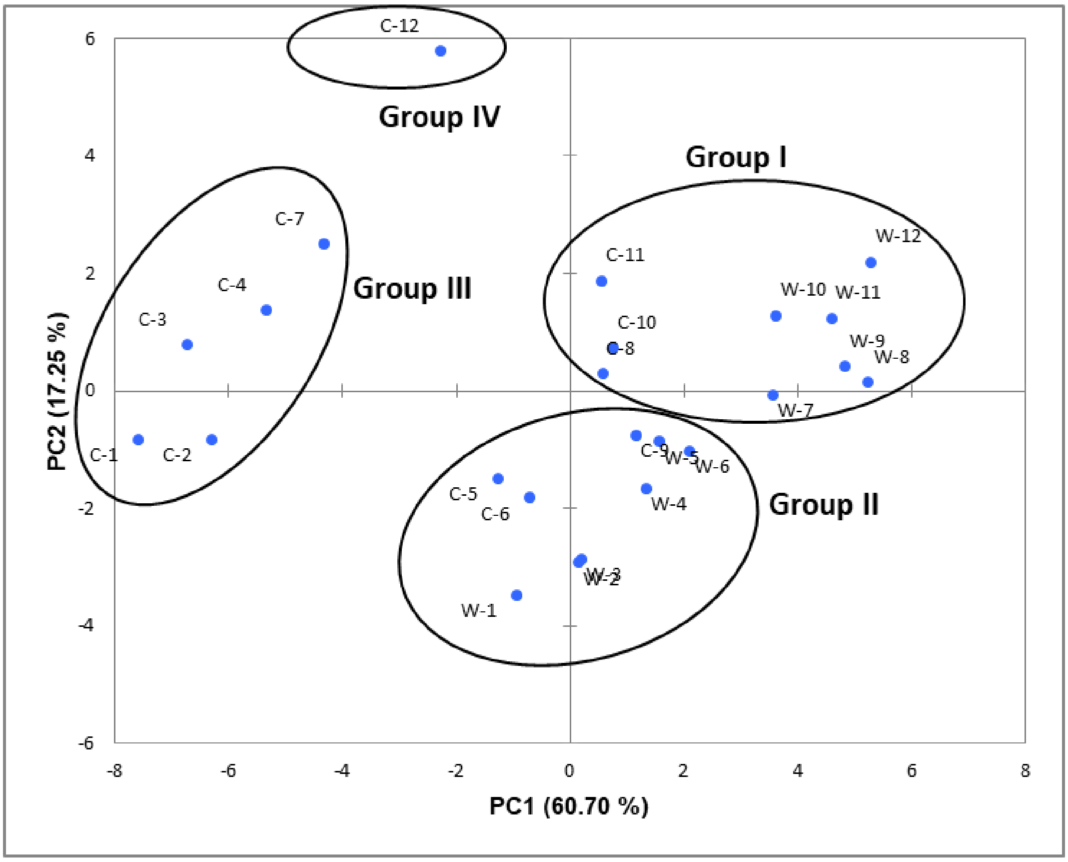

Figure 4.2: Association of the different fertilizer treatments in the warm and cold seasons defined by PC1 and PC2.

Season: c, cold season; w, warm season. Fertilizer combinations (kg ha^{-1}): **1**, 0 NPK 0 N; **2**, 0 NPK 150 N; **3**, 0 NPK 300 N; **4**, 150 NPK 0 N; **5**, 150 NPK 150 N; **6**, 150 NPK 300 N; **7**, 300 NPK 0 N; **8**, 300 NPK 150 N; **9**, 300 NPK 300 N; **10**, 450 NPK 0 N; **11**, 450 NPK 150 N; **12**, 450 NPK 300 N

In the warm season, application of only nitrogen top dressing and 150 NPK basal fertilizer with varied nitrogen top dressing showed a positive correlation with PC1 in Group II. However, in the cold season, the same trend was observed when both NPK basal fertilizer and nitrogen top dressing were 300 kg ha^{-1} each. Therefore this implies that in cold season to obtain similar growth which was obtained by only the

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application of 150 NPK in warm season, an increase of both NPK fertilizer and nitrogen top dressing would be required at 300 kg ha^{-1} each.

The absence of fertilizer application during the warm season as well as maximum application of 150 NPK basal fertilizer with varying nitrogen top dressing in the cold season, showed negative correlation with PC1 as shown in Groups II and III. The combination of 450 NPK and 300 N in the cold season (Group IV) had positive correlation with only PC2.

4.15 Dimensional cluster analysis

Fertilizer treatments in the warm and cold seasons resulted in four clusters in the dendrogram (Figure 4.3). The clusters are grouped according to growing season. The first and second clusters are composed of plants grown in the warm season mainly at 300 and 450 NPK with varying nitrogen top dressing. The second cluster however includes the application of 450 NPK and 150 N in the cold season. Treatment combinations which formed the first and second cluster had the most vigorous growth in all agronomic traits. All these treatment combinations were grown in warm season, except for the combination of 450 NPK and 150 N in the cold season. Therefore the combination of 450 NPK and 150 N in the cold season yielded the same vigorous plant growth as that found in the first and second cluster growing in warm season.

The third cluster consists of plants in the warm season under a maximum application of 150 NPK and varying nitrogen fertilizer, and those grown in the cold season with 300 and 450 NPK at varying nitrogen top dressing. Treatment combinations forming the third cluster all showed moderate growth in the agromic traits. The fourth cluster comprises of plant growth in both warm and cold seasons without fertilizer application (W – 1 and C – 1, respectively); growth in the cold season with only nitrogen top dressing (C – 2 and C – 3) as well as only 150 NPK basal fertilizer (C – 4). Treatment combinations forming the fourth cluster showed poor growth in all agronomic traits.

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4.16 Summary

These results show the effect of different amounts of NPK fertilizer application in different seasons and various agronomic traits of *C. argyrosperma*. Chapter 5 discusses the findings regarding the effect of NPK fertilizer and season in relation to various agronomic traits. The findings are discussed against related research outcomes in the existing literature.

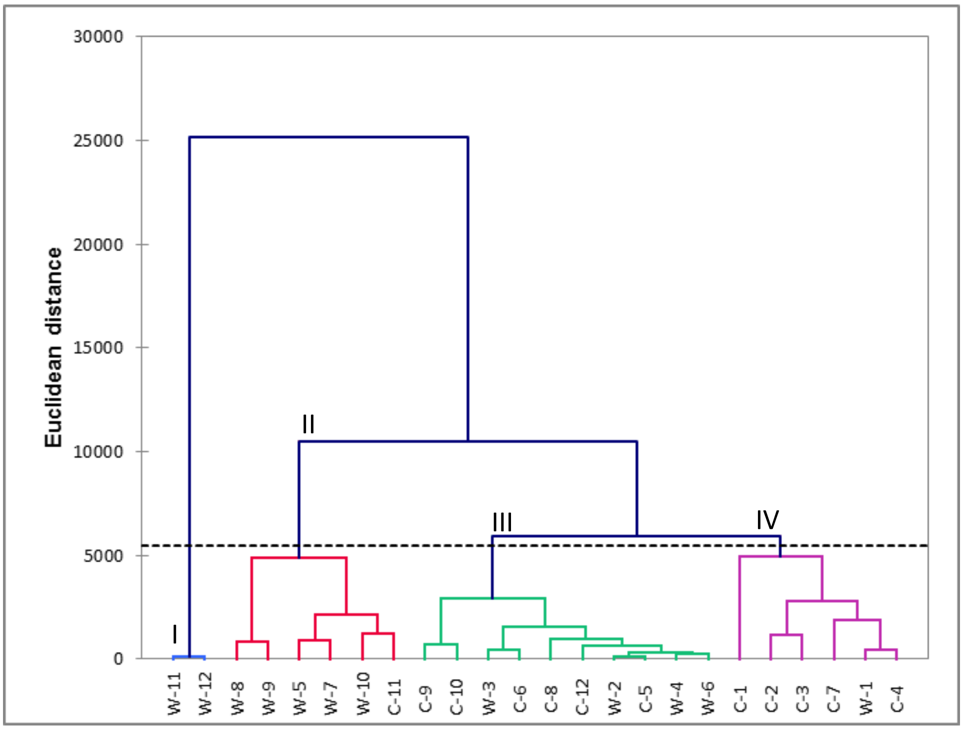

Figure 4.3: Dimensional cluster analysis that presents the relationships between the different fertilizer treatments and season. In the ballots, the hierarchical clustering analysis with the Euclidean distance using the principal component scores is presented.

Season: c, cold season; w, warm season. Fertilizer combinations (kg ha $^{-1}$): **1**, 0 NPK 0 N; **2**, 0 NPK 150 N; **3**, 0 NPK 300 N; **4**, 150 NPK 0 N; **5**, 150 NPK 150 N; **6**, 150 NPK 300 N; **7**, 300 NPK 0 N; **8**, 300 NPK 150 N; **9**, 300 NPK 300 N; **10**, 450 NPK 0 N; **11**, 450 NPK 150 N; **12**, 450 NPK 300 N.

Chapter 5

5 Discussion

5.1 Shoot growth

The application as well as the increase in the amount of both NPK basal fertilizer and nitrogen top dressing resulted in significant increase in shoot growth of *Cucurbita argyrosperma* (Table 4.1). A similar trend was recorded in *Cucurbita pepo* (Oloyede, 2011; Oloyede *et al*. 2012b; Oloyede *et al*., 2013b), *Cucumis sativus* (Eifediyi and Remison, 2009; Jilani *et al*., 2009; Opara *et al.,* 2012; Umekwe *et al.,* 2015), *Luffa acutangular* (Hilli *et al*., 2009), *Lagenaria siceraria* (Jan *et al*., 2000), *Citrullus lanatus* (Sabo *et al.,* 2013) and *Abelmoschus esculentus* (Rahman and Akter 2012) when there was an application of NPK fertilizer. Similar results were also observed in *Cucurbita pepo* (Ng'etich *et al*., 2013; Hamidi *et al*., 2016), *Cucumis sativus* (Yang *et al*., 2009), *Capsicum annum* (Aminifard *et al*., 2012; Ayodele *et al*., 2015) when nitrogen fertilizer was applied. The results on shoot growth show that improved supply of plant nutrients to *C. argyrosperma* through application of NPK basal fertilizer and nitrogen top dressing could have led to better utilisation of carbon and subsequent synthesis of assimilates (Eifediyi and Remison, 2009).

Shoot growth of *Cucurbita argyrosperma* did not differ significantly in the majority of fertilizer treatments in both warm and cold seasons. This concurs with the results found in *Luffa acutangular* (Hilli *et al*., 2009). However, growth under 300 N; 150 NPK and 300 N; as well as 300 NPK and 300 N resulted in longer vines at different stages of growth in the warm than in the cold season. Vigorous shoot growth in the warm than in the cold season was also reported in *Capsicum annuum* (Saha *et al*., 2010). However, in the current research a combination of 450 NPK basal fertilizer and 300 N resulted in higher shoot growth in the cold than in the warm season. Similar results were found in *Abelmoschus esculentus* which had longer vines in the cold than in the warm season (Rahman and Akter 2012). This might confirm that proper plant nutrition is one of the good strategies to alleviate low temperature stress in crop plants (Waraich *et al*., 2012).

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Longer vines were produced when 300 NPK basal fertilizer and 300 N were applied. Season did not cause any significant differences in shoot growth.

5.2 Stem diameter

Significantly thicker stems were produced in *C. argyrosperma* when there was an application and addition of NPK basal fertilizer (Table 4.2). These results are in conformity with those obtained in *Cucurbita pepo* (Oloyede, 2012); *Cucurbita moschata* (Okonwu and Mensah, 2012); *Cucumis sativus* (Opara *et al.,* 2012); *Telfairia occidentalis* (Edu *et al*., 2015); *Amaranthus hybridus*; *Amaranthus cruentus* and *Amaranthus deflexus* (Oyedeji *et al*., 2014). Also, the application of nitrogen top dressing caused an increase in the stem diameter of *Cucurbita pepo* (Ng'etich *et al*., 2013) and *Lycopersicon esculentum* (Abasalt *et al*., 2015). Nitrogen affects plant growth through cell division, cell enlargement and stimulates vegetative growth resulting in larger stem diameter (Ng'etich *et al*., 2013; Valiki *et al*., 2015).

Stem diameter of *C. argyrosperma* increased significantly in the warm than in the cold season. Similar results were obtained in *Cucurbita pepo* (Oloyede *et al*., 2013a). However, differences were not significant in stem diameter of *Solanum melongena* exposed to warm and cold season (Gao *et al*., 2016).

This study showed that *C. argyrosperma* had thicker stems when supplied with a combination 450 NPK basal fertilizer and 300 N in the warm than in the cold season.

5.3 Number of leaves

Cucurbita argyrosperma produced significantly numerous leaves when there was an application as well as an increase in NPK basal fertilizer and nitrogen top dressing (Table 4.3). This trend was also found in a study of *Cucurbita pepo* (Oloyede *et al*. 2012b; Oloyede *et al*. 2013a), *Cucumis sativus* (Odeleye *et al.,* 2006; Eifediyi and Remison, 2009), *Luffa acutangular* (Hilli *et al*. 2009), *Citrillus lanatus* (Sabo *et al.,* 2013), *Amaranthus hybridus*; *Amaranthus cruentus*; *Amaranthus deflexus* (Oyedeji

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et al., 2014) and *Corchorus olitorius* (Ginindza *et al*., 2015). Also, *Cucurbita pepo* (Ng'etich *et al*., 2013; Hamidi *et al.,* 2016), *Capsicum annumm* (Ayodele *et al.,* 2015), *Telfairia occidentalis* (Olaniyi and Odedere, 2009) and *Trifolium alexandrium* (Valiki *et al*., 2015) resulted in significantly numerous leaves when subjected to an increase in nitrogen fertilizer.

The formation of numerous leaves in *Cucurbita argyrosperma* was influenced by warm than cold season. There were more leaves obtained in the warm season than in the cold season in *Luffa acutangular* (Hilli *et al*., 2009). This study showed that in the presence of NPK basal fertilizer, any addition of nitrogen top dressing resulted in numerous *C. argyrosperma* leaves in the warm than in the cold season.

5.4 Growth in leaf area

The application as well an increase in NPK basal fertilizer and nitrogen top dressing caused an increase in growth percentage of the first, second and third leaves in C. *argyrosperma* (Table 4.4). These results are in conformity with those obtained in *Cucumis sativus* (Odeleye *et al*., 2006; Eifediyi and Remison, 2009; Opara *et al*., 2012), *Telfairia occidentalis* (Edu *et al.,* 2015) *Corchorus olitorius* (Ginindza *et al*., 2015) when NPK basal fertilizer was applied. Also, *Cucurbita pepo* (Ng'etich *et al*., 2013), *Cucumis sativus* (Yang *et al.,* 2009), *Capsicum annum* (Ayodele *et al*., 2015), *Spinacia oleracea* (Abdelraouf, 2016) increased with the application of nitrogen fertilizer.

There was more growth percentage in the first and second leaves of *C. argyrosperma* in the warm than in the cold season. This agrees with results in *Citrullus lanatus* (Korkmaz and Dufault, 2001), *Oryza sativa* (Hasani *et al.,* 2013). During vegetative growth, sub-optimal temperatures usually result in slower leaf expansion (Schwarz *et al.,* 2010). However, the third leaf experiences more growth percentage in the cold season.

Higher growth percentage was obtained in the first, second and third leaf from the apex, from plants grown with 450 NPK basal fertilizer and 300 N in the warm season.

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5.5 Total chlorophyll content

Differences in total chlorophyll content of *Cucurbita argyrosperma* were not significant when NPK basal fertilizer was applied as well as when it was increased (Table 4.5). This agrees with results recorded in *Lactuca sativa* and *Cichorium endivia* (Bulgari *et al*., 2014), and *Lactuca hypogaea* (Kekere, 2014). However, the application as well as increase in nitrogen top dressing resulted in a significant increase in total chlorophyll content of *C. argyrosperma* leaves*.* This concurs with the findings in *Momordica dioica* (Vishwakarma *et al*., 2007), *Cucurbita pepo* (Aroiee and Omidbaigi, 2004; Ng'etich *et al*., 2013) and *Solanum tuberosum* (Güler, 2009). Nitrogen, an integral component of chlorophyll, stimulates deep green colour in leaves which enhances the rate of photosynthesis and assimilate absorption (Valiki *et al*., 2015).

Total chlorophyll content in leaves of *C. argyrosperma* increased significantly in the warm than in the cold season. This concurs with results obtained in *Cucumis melo* and *Citrullus lanatus* (Inthichack *et al*., 2014), *Pisum sativum* (Humplik *et al*., 2015) and *Oryza sativa* (Hasani *et al*., 2013).

This study revealed that no significant differences in total chlorophyll were recorded from the leaves of *C. argyrosperma* in the presence of NPK basal fertilizer but any application and increase in nitrogen top dressing resulted in a significantly higher total chlorophyll content in leaves of *C. argyrosperma* only in the warm season.

5.6 Shoot fresh and dry mass, and moisture content

5.6.1 Shoot fresh mass

Shoot fresh mass of *C. argyrosperma* significantly increased when there was an application and an increase in NPK basal fertilizer (Table 4.6). This agrees with results obtained in *Amaranthus hybridus*, *Amaranthus cruentus*, *Amaranthus deflexus* (Oyedeji *et al*., 2014), *Corchorus olitorius* (Ginindza *et al*., 2015) and *Ipomoea batatas* (Kareem, 2013). Also, nitrogen fertilizer application resulted in a significant increase in shoot fresh mass of *C. argyrosperma.* Similar results were

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obtained in *Spinacia oleracea* (Abdelraouf, 2016), *Lycopersicon esculentum* (Wahle and Masiunas, 2003) and *Trifolium alexadrinum* (Valiki *et al*., 2015).

Low shoot fresh mass was obtained from *C. argyrosperma* in cold season. A similar trend was also recorded in *Citrullus lanatus* (Korkmaz and Dufault, 2001), *Capsicum annumm* (Li *et al*., 2015), *Glycine max* (Jenabiyan *et al*., 2015) and *Oryza sativa* (Hasani *et al*., 2013).

This study shows that amongst all fertilizer treatments, a combination of 450 NPK basal fertilizer and 300 N resulted in heavier shoot fresh mass only in the warm season.

5.6.2 Shoot dry mass

Significantly more shoot dry mass was obtained in *Cucurbita argyrosperma* when there was an application and an increase of NPK basal fertilizer (Table 4.6). This agrees with results obtained in *Cucumis sativus* (Salehabadi *et al*., 2014), *Cucurbita pepo* (Oloyede *et al*., 2013b), *Luffa acutangular* (Hilli *et al*., 2009), *Amaranthus hybridus*, *Amaranthus cruentus*, *Amaranthus deflexus* (Oyedeji *et al*., 2014), *Corchorus olitorius* (Ginindza *et al*., 2015) and *Ipomoea batatas* (Kareem, 2013). Also application of nitrogen fertilizer resulted in significantly more shoot fresh mass in *C. argyrosperma.* This confirms results obtained in *Telfairia occidentalis* (Olaniyi and Odedere, 2009), *Spinacia oleracea* (Abdelraouf, 2016), *Lycopersicon esculentum* (Wahle and Masiunas, 2003) and *Trifolium alexadrinum* (Valiki *et al*., 2015).

The warm season resulted in significantly higher shoot dry mass in *C. argyrosperma* than the cold season. This shows that there was more biomass in warm season as a result of long periods of sunlight which was converted by the plant into plant material through the processes of photosynthesis (McKendry, 2002). Similar results were obtained in *Citrullus lanatus* (Korkmaz and Dufault, 2001), *Capsicum annumm* (Li *et al*., 2015), *Glycine max* (Jenabiyan *et al*., 2015) and *Oryza sativa* (Hasani *et al*., 2013), *Luffa acutangula* (Hilli *et al*., 2009); *Cucumis sativus, Cucumis melo* and *Citrullus lanatus* (Inthichack *et al*., 2014).

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This study showed that amongst all fertilizer treatments, a combination of 450 NPK basal fertilizer and 300 N resulted in heavier shoot dry mass only in the warm season.

5.6.3 Shoot moisture content

The application and increase in NPK basal fertilizer resulted in a significant increase in shoot moisture content of *C. argyrosperma* (Table 4.6). Shoot moisture content of *Amaranthus hybridus*, *Amaranthus cruentus*, *Amaranthus deflexus* (Oyedeji *et al*., 2014), *Corchorus olitorius* (Aluko *et al*., 2014) and *Ipomoea batatas* (Kareem, 2013) increased with the application of NPK basal fertilizer. The application and increase of nitrogen top dressing resulted in more shoot moisture content. Results obtained in *Spinacia oleracea* (Abdelraouf, 2016) showed a similar trend.

More shoot moisture content was obtained in the cold than in the warm season. Therefore there was more water content found in shoots of plants grown in cold than warm season as a result of decreased transpiration rate which leads to decreased photosynthetic rate and plant growth processes. Incontratry, shoot moisture increased in the warm than in the cold season in *Lactuca sativa* (Sakamoto and Suzuki, 2015)

This study showed that a combination of 300 NPK basal fertilizer and 150 N resulted in more shoot moisture content in the cold than in the warm season.

5.7 Root fresh and dry mass, and moisture content

5.7.1 Root fresh mass

Root fresh mass of *C. argyrosperma* significantly increased with an application and an increase of NPK basal fertilizer (Table 4.7). This agrees with results obtained in *Amaranthus hybridus*, *Amaranthus cruentus*, *Amaranthus deflexus* (Oyedeji *et al*., 2014), *Amaranthus caudatus* (Olowoake and Adebayo 2014), *Corchorus olitorius* (Ginindza *et al*., 2015) and *Ipomoea batatas* (Kareem, 2013). Nitrogen application resulted in a significant increase in root fresh mass of *C. argyrosperma.* Similar

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results were obtained in *Spinacia oleracea* (Abdelraouf, 2016), *Lycopersicon esculentum* (Wahle and Masiunas, 2003) and *Trifolium alexadrinum* (Valiki *et al*., 2015).

The warm season caused higher root fresh mass than the cold season in *C. argyrosperma* as there was enough sunlight to assist in photosynthesis. This process allowed for more productivity to take placein the plant. This concurs with results obtained in *Citrullus lanatus* (Korkmaz and Dufault, 2001), *Capsicum annumm* (Li *et al*., 2015), *Glycine max* (Jenabiyan *et al*., 2015) and *Oryza sativa* (Hasani *et al*., 2013).

This study showed that amongst all fertilizer treatments, a combination of 450 NPK basal fertilizer and 300 N resulted in plants with heavier root fresh mass only in the warm season.

5.7.2 Root dry mass

Root dry mass of *C. argyrosperma* significantly increased when there was an application and an increase of NPK basal fertilizer (Table 4.7). A similar trend was obtained in *Cucumis sativus* (Salehabadi *et al*., 2014), *Cucurbita pepo* (Oloyede *et al*., 2013a), *Luffa acutangula* (Hilli *et al*., 2009), *Amaranthus hybridus*, *Amaranthus cruentus*, *Amaranthus deflexus* (Oyedeji *et al*., 2014), *Amaranthus caudatus* (Olowoake and Adebayo 2014), *Solanum melongena* (Nafui *et al*., 2011), *Corchorus olitorius* (Ginindza *et al*., 2015) and *Ipomoea batatas* (Kareem, 2013) when an NPK fertilizer was applied. The application of nitrogen fertilizer resulted in a significant increase in root fresh mass of *C. argyrosperma.* This confirms results obtained in *Telfairia occidentalis* (Olaniyi and Odedere, 2009), *Spinacia oleracea* (Abdelraouf, 2016), *Lycopersicon esculentum* (Wahle and Masiunas, 2003) and *Trifolium alexadrinum* (Valiki *et al*., 2015).

Root dry mass of *Cucurbita argyrosperma* increased in the warm season. A similar trend was observed in *Cucumis sativus, Cucumis melo* and *Citrullus lanatus* (Inthichack *et al*., 2014). There was more root dry mass in *Luffa acutangula* (Hilli *et al*., 2009) in the warm season than in the cold season.

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This study showed that amongst all fertilizer treatments, a combination of 450 NPK basal fertilizer and 300 N resulted in heavier root dry mass in the warm than in the cold season.

5.7.3 Root moisture content

The application and increase of NPK basal fertilizer resulted in a significant increase in root moisture content of *Cucurbita argyrosperma* (Table 4.7). Root moisture content in *Ipomoea batatas* (Kareem, 2013) increased significantly with NPK basal fertilizer application.

Root moisture content increased significantly in the cold than in the warm season. However, the opposite effect was observed in *Lactuca sativa* (Sakamoto and Suzuki, 2015).

This study showed that a combination of 150 NPK basal fertilizer and 300 N resulted in more root moisture content in the cold than in the warm season.

5.8 Number of flowers

5.8.1 Staminate flowers

The application as well as the increase in the amount of both NPK basal fertilizer and nitrogen top dressing resulted in significant increase in the number of staminate flowers in *C. argyrosperma* (Table 4.8). This conforms with results obtained in *Cucurbita pepo* (Agbaje *et al*., 2012) and *Cucumis sativus* (Nwofia *et al.,* 2015; Umekwe *et al*., 2015) when there was an application of NPK fertilizer. There was an increase in the number of staminate flowers of *Cucurbita pepo* (Hamidi *et* al., 2016; Ng' etich *et al*., 2013) when nitrogen fertilizer was applied.

In the earlier stages of growth in *C. argyrosperma,* more staminate flowers were recorded in the cold than in the warm season. This increase in the number of staminate flowers in the cold season is in agreement with results recorded in *Cucumis sativus* (Nwofia *et al.,* 2015). It is also confirmed in *Cucurbita pepo* (Wein *et al*., 2004) as warm temperature delays formation of staminate flowers. However, in

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the later stages of growth, plants grown in the warm season under different fertilizer treatments had significantly numerous staminate flowers than those grown in the cold season. This is in agreement with results obtained in of *Cucurbita pepo* (Agbaje *et al*., 2012) in the warm season.

Results of this study showed that amongst all fertilizer treatments, a combination of 300 NPK basal fertilizer and 150 N resulted in numerous staminate flowers in the warm season.

5.8.2 Pistillate flowers

The application as well as the increase in the amount of both NPK basal fertilizer and nitrogen top dressing resulted in significant increase in the number of pistillate flowers in *Cucurbita argyrosperma* (Table 4.8). This concurs with result obtained in *Cucurbita pepo* (Agbaje *et al*., 2012) and *Cucumis sativus* (Nwofia *et al.,* 2015) when NPK fertilizer was applied. Pistillate flowers in *Cucurbita moschata* (Swiader and Moore, 2002) and *Cucurbita pepo* (Ng'etich *et al*., 2013; Hamidi *et al.,* 2016) increased when nitrogen fertilizer was applied.

The number of pistillate flowers did not differ significantly in *Cucurbita argyrosperma* in both the warm and the cold season. However, there were numerous pistillate flowers in the cold than in the warm season on untreated plants as well as plants grown with only 150 N. More pistillate flowers were recorded in the cold than in the warm season in *Cucumis sativus* (Nwofia *et al.,* 2015).

Numerous pistillate flowers were produced from *Cucurbita argyrosperma* grown with the application of 450 NPK basal fertilizer and 150 N. Season did not cause any significant differences in the number of pistillate flowers in *Cucurbita argyrosperma*.

5.9 Number of fruits per plant, mass and size

5.9.1 Number of fruits per plant

The application as well as the increase in the amount of both NPK basal fertilizer and nitrogen top dressing resulted in significant increase in the number of fruits per plant

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in *Cucurbita argyrosperma* (Table 4.9). Similar findings were obtained in *Cucumis sativus* (Odeleye *et al*. 2006; Eifediyi and Remison, 2009; Umekwe *et al.,* 2015; Nwofia *et al.,* 2015) when NPK fertilizer was applied. This significant increase in the number of fruits per plant when NPK fertilizer is applied may be an indication that the nutrients which are taken up by the plant are well utilised for cell multiplication, amino acid synthesis and energy formation (Eifediyi and Remison, 2009). Also the number of fruits significantly increased in *Momordica charantia* (Heidari and Mosbari, 2012) when nitrogen fertilizer was applied.

Numerous fruits per plant were recorded in *Cucurbita argyrosperma* in the warm than in the cold season. A similar trend was observed in *Cucumis sativus* (Nwofia *et al.,* 2015) and in *Luffa acutangular* (Hilli *et al*. 2009).

Amongst all fertilizer treatments, a combination of 450 NPK fertilizer and 150 N resulted in more fruits per plant in *Cucurbita argyrosperma* only in the warm season.

5.9.2 Fruit mass and size

The application as well as the increase in the amount of both NPK basal fertilizer and nitrogen top dressing resulted in significant increase in mass, diameter and length of *Cucurbita argyrosperma* fruits (Table 4.9). Higher fruit mass was recorded in *Cucurbita pepo* (Hamidi *et al.,* 2016; Sabo *et al*., 2013), *Cucumis sativus* (Odeleye *et al*. 2006; Eifediyi and Remison, 2009; Umekwe *et al.,* 2015; Nwofia *et al.,* 2015), *Citrillus lanatus* (Sabo *et al.,* 2013) and *Lagenaria siceraria* (Jan *et al.,* 2000) when NPK fertilizer was applied. Longer fruits were recorded in *Cucurbita pepo* (Ng'etich *et al*., 2013; Sabo *et al*., 2013) and *Cucumis sativus* (Eifediyi and Remison, 2009; Nwofia *et al.,* 2015) when there was an application of NPK fertilizer. Also, fruit diameter increased in *Cucurbita pepo* (Ng'etich *et al*., 2013; Sabo *et al*., 2013), *Cucumis sativus* (Eifediyi and Remison, 2009; Nwofia *et al.,* 2015) and *Lagenaria siceraria* (Jan *et al.,* 2000) when NPK fertilizer was applied.

Heavier fruits were obtained in the warm than in the cold season. This agrees with results obtained in *C. argyrosperma* (Nunez-Grajeda and Garza-Ortega 2005), *Luffa accutangular* (Hilli *et al*. 2009), *Citrullus lanatus* (Sabo *et al.,* 2013) and *Lycopersicon*

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esculentum (Adams *et al.*, 2001). Both wider and longer *C. argyrosperma* fruits were recorded in the warm season. This confirms results obtained in *Cucumis sativus* (Nwofia *et al.,* 2015).

Heavier, wider and longer *C. argyrosperma* fruits were obtained when both NPK basal fertilizer and nitrogen top dressing were at 300 kg ha^{-1} each, only in the warm season.

5.10 Number of seeds per fruit, mass and size

5.10.1 Number of seeds per fruit

Cucurbita argyrosperma produced significantly numerous seeds when there was an application as well as an increase in NPK basal fertilizer and nitrogen top dressing (Table 4.10). This trend was also shown in a study of *Telfairia occidentalis* (Akanbi *et al*., 2007) and *Citrullus lanatus* (Olaniyi, 2006) when NPK basal fertilizer was applied. Also, the number of seeds in *Capsicum annum* (Aminifard *et al*., 2012) increased with the application of nitrogen fertilizer. In this study, the heaviest fruits had the highest number of seeds. Fruits of *Cucurbita pepo* with the heaviest fruit weight were observed to produce more seeds than fruits which had the lowest fruit weight (Oloyede *et al.*, 2013b).

There were more seeds per fruit obtained in the warm than in the cold season. This agrees with results obtained in *Luffa acutangula* (Hilli *et al*., 2009).

This study showed that *C. argyrosperma* produced more seeds per fruit in plants with an application of 300 NPK basal fertilizer and 300 N, in the warm season.

5.10.2 Total seed mass per fruit

The application as well as the increase in the amount of NPK basal fertilizer and nitrogen top dressing resulted in significant increase in total seed mass of *Cucurbita argyrosperma* (Table 4.10). This agrees with findings in *Cucurbita moschata* (Manjunath Prasad *et al*., 2007; Alekar *et al*., 2015), *Lagernaria siceraria* (Ibrahim

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and El-Kader, 2015), *Telfairia occidentalis* (Akanbi *et al*., 2007), *Citrullus lanatus* (Olaniyi and Tella, 2011) when NPK fertilizer was applied.

More seed mass was obtained in the warm than in the cold season. Similar findings were also abtained in *Luffa acutangula* (Hilli *et al*., 2009).

Cucubita argyrosperma fruits which were grown in the warm season with the application of 300 NPK basal fertilizer and 300 N, had heavier seeds per fruit.

5.10.3 Hundred seed mass

The application as well as the increase in NPK basal fertilizer and nitrogen top dressing did not cause any significant differences in hundred seed mass of *C. argyrosperma* (Table 4.10). This is contrary to findings in *Lagenaria siceraria* (Ibrahim and El-Kader, 2015) when NPK basal fertilizer was applied. However, these findings concur with findings in *Helianthus annuus* (Mujiri and Arzani, 2003) when nitrogen fertilizer had insignificant effect on hundred seed mass.

Hundred seeds of *C. argyrosperma* were heavier in the warm than in the cold season. These results contradict findings in *Psoralea corylifolia* (Sumathi *et al*., 2013).

The results of this study show that hundred seed mass of *C. argyrosperma* is not reliant on NPK basal fertilizer and nitrogen top dressing but rather on seasons.

5.10.4 Seed size

Cucurbita argyrosperma produced significantly longer, wider and thicker seeds when there was an application as well as an increase in NPK basal fertilizer and nitrogen top dressing (Table 4.10). However, in *Phaseolus vulgaris* (Ogutu *et al.,* 2012), the application of nitrogen caused an increase in seed length, width and thickness. In this study, bigger seeds were obtained from larger fruits. Nerson (2007) discovered that in most seeded plants there is a positive correlation between fruit size and seed size.

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Longer, wider and thicker seeds were obtained in the warm than in the cold season. Longer, wider and thicker seeds were obtained in *Phaseolus vulgaris* (Ogutu *et al.,* 2012) in the warm season.

In this study, it was observed that lager fruits had larger seeds and the warm season favoured the production of longer, wider and thicker seeds.

5.11 Principal component analysis and correlation

The first component which had high variability accounted for 60.70% of the total variation and was mainly defined positively by all traits except moisture content (Table 4.11). In *Cucurbita maxima*, *C. moschata* and *C. pepo* fruit mass, fruit width and 100 seed mass had a positive correlation but negative correlation with fruit length in principal component analysis (Martins *et al*., 2015). Also, in *Cucumis sativus*, the number of staminate and pistillate flowers, the number of fruits, fruit mass, fruit width and fruit length, accounted for most of the variability in different principal components (Nwofia *et al*., 2015).

A significant positive correlation was recorded among all agronomic traits except a negative correlation with shoot moisture content (Table 4.12). Similar positive correlation was determined between plant height and stem diameter in *Lycopersicon esculentum* (Abasalt *et al*., 2015) and, plant height and number of leaves in *Citrullus lanatus* (Sabo *et al*., 2013). In *Cucurbita pepo*, staminate and pistillate flowers *(*Ng'etich *et al*., 2013); as well as the number of fruits and fruit length, fruit diameter, fruit width (Oloyede *et al*., 2013b), had a positive correlation with each other. Further, shoot fresh and dry mass correlated positively in *Ipomoea batatas* (Kareem, 2013). A positive correlation indicated the extent to which these traits increased parallel to one another.

A positive definition with PCA and significant positive correlation of all measured agronomic traits except shoot and root moisture content, were explained as proper traits to measure growth and yield in *C. argyrosperma*. These traits can also be used in future breeding of this species.

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5.12 Scatter plot and dimensional cluster analysis

In scatter plot, all agronomic traits had a positive association either in PC1, PC2 or both principal components (Figure 4.1). The shoot length, shoot and root dry mass of *Acaciella angustissima* treated with different NPK fertilizer amounts also associated themselves positively in a scatter plot (Ruiz-Valdiviezo *et al*., 2009).

The NPK fertilizer treatments with a minimum of 300 kg ha $^{-1}$ at varying nitrogen top dressing concentrations, in both cold and warm seasons was posively defined by PC1 and PC2 (Group I) (Figure 4.2). These treatments in both seasons also formed Cluster II in the dendogram (Figure 4.3).This probably meant that such fertilizer combinations regardless of season promoted growth and yield in *C. argyrosperma*. An increase in NPK fertilizer application promoted growth and yield in *C. pepo* (Oloyede *et al*., 2013a) and *Luffa acutangular* (Hilli *et al*., 2009).

A general grouping of low fertilizer in the warm season and high fertilizer in the cold season with negative definition by PC1 and/or PC2 might indicate unfavourable growth and yield conditions for *C. argyrosperma* (Group II and III) (Figure 4.2). The best agronomic traits of *Cucumis sativus* grown in the warm season was associated with cluster analysis (Ene *et al*., 2016). Sub-tropical crops including cucurbits suffer from physiological disorders when they are exposed to intense and prolonged low temperatures, which leads to irreversible cell dysfunction and eventualy plant death (Kozik and Wehner 2014).

The overall results suggest that the agronomic traits in the warm season out competed those in the cold season. This might explain the best growth and yield conditions for *C. argyrosperma* as a sub-tropical to tropical crop (Schwarz *et al*., 2010). However, it was also evident that high (450 kg ha^{-1}) NPK basal fertilizer application with varying (150 and 300 kg ha^{-1}) nitrogen top dressing in cold season could promote growth and yield of *C. argyrosperma*. Therefore, based on the overall results, both research hypotheses were supported. Chapter 6 provides conclusions on key research findings as well as recommendations for proper NPK fertilizer application and the right season in which *C. argyrosperma* can be grown for enhanced growth and yield.

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Chapter 6

6 Conclusions and Recommendations

Longer vines, more fruits per plant and larger fruit size were produced when plants were grown with application of 300 NPK basal fertilizer and 300 N. This study showed that *C. argyrosperma* had thicker stems, higher growth percentage in first, second and third leaf, heavier shoot and root fresh mass, and root fresh mass when grown with a combination 450 NPK basal fertilizer and 300 N. However, in the presence of NPK basal fertilizer, any addition of nitrogen top dressing resulted in numerous *C. argyrosperma* leaves. The application of NPK basal fertilizer did not cause any significant differences in total chlorophyll content of *C. argyrosperma* leaves but only when there was an application as well as an increase in nitrogen top dressing. A combination of 150 NPK basal fertilizer and 300 N resulted in more root moisture content and numerous staminate flowers.

Numerous pistillate flowers and fruits per plant were produced from *Cucurbita argyrosperma* grown with the application of 450 NPK basal fertilizer and 150 N. Hundred seed mass of *C. argyrosperma* is not reliant on NPK basal fertilizer and nitrogen top dressing. The hypothesis for proper application of fertilizer was supported by the results since there was an increase in growth and yield in *C. argyrosperma*.

The hypothesis postulated for season predicted that the growing season increased the growth and yield of *C. argyrosperma*. The results supported the prediction as the warm season (23° – 33°) which is the growing season resulted in thicker stems, numerous leaves, more growth percentage in the first and second leaf from the apex, higher total chlorophyll content, heavier shoot fresh and dry mass, heavier root fresh and dry mass, numerous staminate flowers, more fruits per plant, larger fruit size, numerous seeds per fruit, higher seed mass per fruit and heavier hundred seed mass. However, the cold season (16° – 25°) resulted in more growth percentage in the third leaf, higher shoot and root moisture content. Insignificant differences were obtained in shoot growth as well as pistillate flowers, and season had no effect on these traits.

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The application as well as the increase in NPK basal fertilizer and nitrogen top dressing resulted in an increase in growth, yield and crop quality of *Cucurbita argyrosperma*, in the warm season in Northern Zululand*.* It is therefore recommended that farmers should apply NPK basal fertilizer and nitrogen top dressing at 300 kg ha^{-1} each to produce maximum vegetative growth, high fruit and seed yield in *C. argyrosperma*.

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