EFFECT OF CULTIVAR AND PLANTING PERIOD ON GROWTH, YIELD, MUCILAGE AND NUTRITIONAL COMPOSITION OF *CORCHORUS OLITORIUS* UNDER FIELD AND SHADE HOUSE CONDITIONS

BY

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MINI-DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

HORTICULTURE, DEPARTMENT OF PLANT PRODUCTION, SOIL SCIENCE AND AGRICULTURAL ENGINEERING

in the

FACULTY OF SCIENCE AND AGRICULTURE

SCHOOL OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

at the

UNIVERSITY OF LIMPOPO

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MARCH 2022

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DECLARATION

I, Pabalelo Emmanuel Mothoa, declare that the content of this mini-dissertation submitted to the University of Limpopo for the degree of Master of Science in Horticulture, represents my own work and has not been submitted previously by me or anybody for academic examination towards any qualification at this or any other University. This is my work in design and execution and related materials contained herein have been duly acknowledged. Furthermore, it represents my own opinions and not necessarily those of the University.

			03/03/2022
Candidate	: P.E Mothoa	Signature	Date

DEDICATION

A special dedication to my late father (David), my mother (Rose), brother (Mpho), sisters (Tebogo, Khomotjo, Katlego, Khutjo), and the Mothoa family at large who have always desired the best for me and helped me through all walks of life.

ACKNOWLEDGEMENTS

I would like to convey my sincere gratitude to almighty God for allowing me to pursue this study to completion. Completion of this study was without a doubt not an individual but a collective effort of several people who contributed in many ways. I would like to acknowledge and thank my supervisor Professor VI Ayodele for her patience, support, time, encouragement, guidance and assistance with the planning, preparation and monitoring of this research throughout to make it a success. I will forever cherish the exposure, skills and experience I acquired under her supervision. She brought out the best in me, allowed me to grow as an individual and her critical views played a pivotal role in my studies. I would like to sincerely acknowledge and unreservedly thank my co-supervisor Professor IK Mariga for his guidance, support, feedback and his motivation which helped me learn and conduct myself in a professional way. I am thrilled to express my appreciation for the time he set aside to give inputs, go through some papers and the ideas shared with me. I feel remarkably honoured to have had a co-supervisor who inspired me to continuously explore and strive to be more knowledgeable. I would like to extend my thankfulness to Professor PW Mashela and his team for allowing me to use some of their research equipment to ease and aid fluent progress and completion of my study. I am appreciative of Professor KK Ayisi's kindness in allowing me to use some of the equipment from his centre. I would like to extend my sincere gratitude to Mr SS Thosago and Doctor LT Tyasi for their tireless assistance with statistical software and analysis of the results. A special mention goes to the Department of Plant Production, Soil Science and Agricultural Engineering stuff at large, particularly the technical team. I humbly extend appreciation to my fellow colleague Mr TFM Makola for his assistance in carrying out the experiment. Special gratitude goes to Ms NP Ngoveni who has provided moral and emotional support consistently and without fail to date. This would not happen without the love and support from my family, who encouraged, advised, and served as source of strength throughout the years. I will forever be grateful to the National Research Foundation for the generous scholarship to fund the project and to the University of Limpopo for providing the platform, opportunity and resources to perform the study. Above all, I thank almighty God for guidance, strength and protection to see this project through.

CONFERENCE CONTRIBUTIONS

1. Mothoa, P.E., Ayodele, V.I. and I.K. Mariga. 2019. *Mucilage content and growth of three Corchorus olitorius cultivars in response to planting date and growing condition*. The 10th Faculty of Science and Agriculture Postgraduate Research Day, University of Limpopo, Polokwane. 19-20 September, 2019.
2. Mothoa, P.E., Ayodele, V.I. and I.K. Mariga. 2020. *Biomass production and chlorophyll content of three Corchorus olitorius cultivars in relation to planting date*. Combined Congress, University of Free State, Bloemfontein. 20-23 January, 2020.
3. Mothoa, P.E., Ayodele, V.I. and I.K. Mariga. 2021. *Influence of planting period on phenology, yield and yield components of three Corchorus olitorius cultivars under two growing conditions.* All Africa Horticultural Congress, Senegal, Dakar. 29-31 March, 2021.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
*	Significant
°C	Degrees Celsius
ALVs	African leafy vegetables
ANOVA	Analysis of variance
$C0_2$	Carbon dioxide
Ca	Calcium
cm	Centimetres
Cv.	Cultivar
DAFF	Department of Agriculture, Forestry and Fisheries
DF	Degree of freedom
EC	Electrical conductivity
et al.	And others
FAO	Food and Agriculture Organisation
Fe	Iron
Fig.	Figure
g	Grams
GC	Growing condition
GTRC	Green Technologies Research Centre
ha^{-1}	Per hectare
K	Potassium
KCl	Potassium chloride
kg	Kilogram
kg/ha	Kilogram per hectare
kg^{-1}	Per kilogram
LAN	Lime ammonium nitrate
m	Metres
m/s	metres per second
Max	Maximum
Mg	Magnesium
Min	Minimum

mm	Millimetres
Mn	Manganese
mPa.s	Centipoise
MS	Mean square
N	Nitrogen
Na	Sodium
No.	Number
NRF	National Research Foundation
NS	Non-significant
P	Phosphorus
pH	Potential of hydrogen ion concentration
PP	Planting period
RCBD	Randomized Complete Block Design
Rep	Replication
RH	Relative humidity
SAWS	South African Weather Service
SS	Sum of squares
WAT	Weeks after transplanting
Zn	Zinc
mg/kg	Milligram per kilogram

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ABSTRACT

The awareness of the nutritional benefit and consumption of the Jew's mallow (*Corchorus olitorius* L.) especially in South Africa is low; this is predominantly because of lack of access and availability of the crop in the market. This research aimed to determine to what extent would the planting period affect mucilage, growth, yield and nutritional composition of the selected *C. olitorius* cultivar under different growing conditions and provide a better understanding and scientific evidence for the producers to maximize production. The experiments were carried out simultaneously, the first experiment (field trial), was on the field and the second (pot trial) in the shade house. Treatment factors were: 2 x growing conditions (field and pot), 4 x planting periods (November, December, January and February) and 3 x *C. olitorius* cultivars ('Local', 'Oniyaya' and 'Amugbadu'). The experiments were carried out as randomised complete block design (RCBD) arranged in split-spilt plot with three replications. Growing condition was the main factor, planting period as the sub-factor, while the cultivars were the sub-subplot factor. Mucilage content, growth and yield parameters were measured and nutritional composition of the crop was determined from harvested plant samples.

Mucilage content of *C. olitorius* varied with cultivar and growing condition. The significantly ($P < 0.05$) highest quantity of mucilage at 8 WAT was obtained from Oniyaya cultivar under field condition whereas the least was recorded from Local cultivar under pot condition. The mucilage content of the three cultivars did not differ significantly ($P \leq 0.05$) at 6 WAT, however significant ($P < 0.01$) differences were recorded at 8 WAT. The cultivar Oniyaya produced significantly highest average (184.58 mPa·s) mucilage content at 8 WAT while the lowest average value (124.58 mPa·s) was recorded in the Local cultivar. This implies that Oniyaya cultivar produced the slimiest plants. The mucilage content of Jew's mallow appears to decline over time; thus, the crop had higher mucilage content when young and tender.

Selected growth parameters such as chlorophyll, number of leaves and stem diameter were significantly affected by the combined effect of cultivar, planting period and growing condition. For example, the average highest chlorophyll content was obtained in Oniyaya cultivar during November period under pot conditions. While the greatest number of leaves at 8 WAT were obtained in Oniyaya and Local cultivars during

December planting period and in Amugbadu during November period all under the field conditions. All cultivars grown during the February planting period had the lowest average number of leaves.

Growth parameters such as number of branches, plant height and leaf area were not significantly ($P \leq 0.05$) affected by the combined effect of cultivar, planting period and growing condition. Significant ($P < 0.05$) combined effect of cultivar and planting period was recorded on number of *C. olitorius* branches at 6 WAT. Furthermore, significant interaction between planting period and growing condition was also recorded. The significantly higher number of branches at 6 WAT was obtained from Oniyaya and Amugbadu cultivars during the November planting period. The test crop seedlings transplanted in February had the lowest average number of branches. Comparing the cultivars at 6 and 8 WAT, Oniyaya produced significantly ($P < 0.01$) higher number of branches than Local. Local cultivar was significantly taller than others under the field condition; while significantly tallest plant was obtained during December period under the same condition. The differences observed in *C. olitorius* shoot and root fresh and dry masses were not significantly different in their responses in relation to the combined effect of cultivar, planting period and growing condition. However, the significantly highest average fresh shoot mass was obtained during December period and the lowest average values in February planting period.

The combined effect of cultivar, planting date and growing condition had significant ($P < 0.01$) influence on number of days to 50% flowering; pod formation and pod maturity of *C. olitorius*. The significantly longest average number of days to 50% flowering was observed in Oniyaya and Amugbadu cultivars during November period under field condition, while Local cultivar flowered at the shortest period, but produced highest number of pods and seed yield during the December planting period under the same condition.

Cultivar, planting date and growing condition had significant ($P < 0.01$) influence on Zinc contents of *C. olitorius.* Whereas the three factors had no significant effect on N, Ca, Mg, K, Na, Mn, Fe, P, Al, ash and dry matter contents of the crop. The highest average amounts of N, Mg and K were obtained from Local cultivar during November period while the same cultivar produced the highest average amount of Ca during December period. In conclusion, the mucilage content and fresh shoot mass (which is

the marketable part of *C. olitorius)* were optimal in crops grown during the December planting period when the temperatures are at the highest. While better nutritional content of the crop was better attained during the November planting period. Both November and December planting periods allowed *C. olitorius* to reach its maximum growth capacity, translating to higher yielding parameters than other planting periods.

Keywords: Cultivar, planting period, growing condition, mucilage, *Corchorus olitorius*

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background of the study

Jew’s mallow (*Corchorus olitorius* L.) is amongst most important leafy vegetables in many countries such as Egypt, Nigeria and Sudan and it is almost as equally important in many other countries around the world such as India and Japan (Rashwan, 2011; Samra *et al*., 2007). South African local names for Jew’s mallow include, *thelele* in Sesotho, Sepedi and Setswana; *guxe* in Xitsonga; and *delele* in Tshivenda (Van Rensburg *et al*., 2004). The two cultivated species (*C. olitorius* and *C. capsularis*) in Asia were determined to originate from Africa, through nuclear and chloroplast simple sequence repeats (SSRs) study (Kundu *et al*., 2013). Their study is also backed by numerous interrelated species and existing plant types which are widely spread across the African continent (Benor *et al*., 2012). On the other hand, Bangladesh, North India and Myanmar are thought to be secondary centres of origin (Basu *et al*., 2004). Additionally, there are some *Corchorus* species like *C. asplenifolius*, *C. trilocularis, C. tridens* and *C. olitorius* which are reportedly found in South Africa (Schippers *et al*., 2002; Van Wyk and Gericke, 2000).

Jew's mallow is an erect annual herb that grows to a height of 0.2 to 1.5 m, depending on the cultivar (Mguis *et al*., 2014). It has simple oblong to lanceolate leaves with serrated margins and prominent hair-like teeth at the base grow on angular stalks. The little bright yellow flowers are followed by an angular capsule as the fruit (Mguis *et al*., 2014). Several studies across the world have shown that *C. olitorius* has a high morphological diversity (Habib *et al*., 2015). The stem is long and slender with colour ranging from green to light red or deep red. The pods are elongated, and the tap root system is extensively branched. Jew's mallow’s seeds have a high dormancy that can be disrupted with a hot water treatment (Schippers *et al*., 2002). The crop generally produces pods and leaves that differ in size, branching and shape.

Jew's mallow is a common green leafy vegetable and the most widely farmed *Corchorus* species in both arid and semi-arid climates throughout Africa's humid regions (Bamigboye, 2011). This crop flourishes in sandy, low-organic-matter soils that are well-drained and have plenty of moisture. A wet climate with temperatures ranging from 25ºC to 32ºC and rainfall between 600 and 2000 mm/year is optimum for its growth. Jew's mallow grows well under high temperature and high humidity and its harvesting usually begins 40-60 days after planting (Rashwan, 2011).

The crop is consumed either fresh or dried (Rashwan, 2011). It contains carotene and other carotenoids, vitamins B1, B2, C and E and minerals, Jew's mallow is often consumed as a health vegetable (Mahmoud *et al*., 2014). The leaves of *C. olitorius* are well-known for their emollient, diuretic, tonic, and purifying properties (Fagbohoun and Ibrahim, 2011; Adebo *et al*., 2018). Its leaves are also used to prepare a sticky sauce that is served as relish with starchy food, such as maize thick porridge. Amino acids and vital minerals abound in the leaves which are used to treat malaria and typhoid fever with herbal pharmacopoeia (Habib *et al*., 2015). In Kenya, root scrapings of *C. olitorius* are used to alleviate toothaches, whilst in Nigeria, laxative mixtures made from seeds are utilized (Ufoegbune *et al*., 2016). A slimy sauce is made with a powder made from the dried leaves. Jew's mallow leaves can be cooked with cowpeas, pumpkins, cocoyam leaves, sweet potatoes, milk and butter, pork, and peppers and lemon in East Africa.

The capability of the leaves to produce mucilage is valued in the preparation of sauces that can be combined with starchy foods (Ngomuo *et al*., 2017). Mucilage of *C. olitorius* is reported to be an acidic polysaccharide consisting of galacturonic acid, galactose, mannose, glucose and arabinose (Tsukui *et al*., 2004). The viscosity of the leaves is due to the mucilaginous polysaccharide in the leaves, which is widely appreciated by individuals who consume the plant as a vegetable. This polysaccharide is composed of rhamnose, galactose, glucose, galacturonic acid and glucuronic acid and is high in uronic acid (65%) (Adediran *et al*., 2015).

1.2 Problem statement

Research has resulted in the dissemination of information about the importance of fresh vegetables in human diets (Oniango, 2001). Edible leaves are commonly grown from vegetables such as *Amaranthus hybridus* and *C. olitorius* (Ojeifo *et al*., 2006). In many nations, these leafy vegetables are traditionally consumed as food. Beta carotene, ascorbic acid, minerals, and dietary fibre are abundant in Jew's mallow (Negi and Roy, 2001). However, to get the best out of this crop it must be planted at the right time. In South Africa, Jew's mallow is typically harvested in the wild rather than cultivated (Venter *et al*., 2004).

Jew's mallow is known to be a summer crop as it naturally grows in that season and there is adequate research done on the suitable seasons to grow the crop (Rashwan, 2011). However, there is no scientific literature available about appropriate planting time for this crop in South Africa. There is a need to plant at the right time, but firstly the grower needs to know when it is the right time to plant which *C. olitorius* cultivar, and this is the aspect this research intends to clarify. This research aimed to determine to what extent the planting period will affect growth and yield of selected cultivars and provide a better understanding and scientific evidence for the producers to maximize production.

1.3 Motivation of the study

Planting Jew's mallow at the appropriate time of the season may have a considerable effect on its growth, yield and nutritional quality. Jew's mallow is a summer and heat demanding crop and therefore not tolerant to cold temperatures and frost (Shiwachi *et al*., 2008). There is limited information with regards to appropriate planting period for *C. olitorius* in Limpopo Province and this information is fundamental, not only to maximize current production, but also for commercialization of the crop in South Africa. One of the objectives for every farmer is to maximize production with minimum inputs, thus for maximum growth rate and production of *C. olitorius* the appropriate planting period and the suitable cultivar for a particular growing condition should be known.

Jew's mallow is well-known for its significant role in the diet, providing nutrients and making food more appetizing. As it comprises of carotene and other carotenoids, vitamins B1, B2, C, and E, and minerals, the crop is often consumed as a health vegetable (Mahmoud *et al*., 2014). In South Africa, *C. olitorius* is found in the wild and consumed in relatively few households. In Limpopo Province, this crop is sometimes grown in home gardens in very few households for consumption purposes and is rarely available in the market (DAFF, 2012). The information obtained from this research will potentially help growers to maximise production and encourage commercialization of the crop in South Africa. This will also help to improve livelihood of farmers and community through improved nutrition and income generation, thus increasing food security in South Africa, particularly at the household level and subsequently at national level.

1.4 Aim of the study

The aim of the study was to establish the effect of planting period, cultivar and growing environment on growth, yield, mucilage and nutritional composition of *Corchorus olitorius* in Capricorn district of Limpopo Province.

1.5 Objective of the study

The objective of the study was to assess the growth, yield, mucilage and nutritional composition response of three *C. olitorius* cultivars to planting period under field and shade house conditions.

1.6 Hypothesis

Cultivar and planting period and their interaction have no effect on growth, yield, mucilage and nutritional composition of *C. olitorius* under field and shade house conditions.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin and Distribution of *Corchorus olitorius*

The genus *Corchorus*, belongs to the *Tiliaceae* plant family, with roughly 50 to 60 species that can be found in the tropics, subtropics and warm temperate zones worldwide (Morakinyo, 1997). According to Makinde *et al.* (2009), the occurrence of various wild vegetable species and weedy relatives has led to a generally held idea that *C. olitorius* is native to Africa, whereas some writers have argued that it is native to India, Indo-Burma, or Sri Lanka. According to a study by Bamigboye (2011), *C. olitorius* was domesticated in Asia, however it is more likely that the plant's wild ancestors originated in Sub-Saharan Africa and were transported to Asia, where an ennobled form arose. Furthermore, Africa is home to the majority of its species, with many of them found in Egypt, Nigeria, Ethiopia, Tanzania, and South Africa. Farming with *Corchorus spp* is thought to have begun 200 years ago in Africa's tropics (Makinde *et al*., 2009).

In various areas, including Egypt, Southern Asia, Japan, India, China, Lebanon, Palestine, Syria, Jordan, Tunisia and Nigeria, Jew's mallow is an essential green leafy vegetable (Loumerem and Alercia, 2016). In the Ivory Coast, Benin, Nigeria, Cameroon, Sudan, Kenya, Uganda and Zimbabwe, it is a prominent leafy vegetable. In the Caribbean, Brazil, India, Bangladesh, China and the Middle East, it is also produced as a green vegetable (Loumerem and Alercia, 2016). It is widely farmed and popular throughout West Africa, particularly in Nigeria, among people of all social groups (Oyedele *et al*., 2006) and in most parts of Africa (Velempini *et al*., 2004). Furumuto *et al*. (2002) stated that Jew’s mallow is also eaten in Egypt as a staple food since the time of the Pharaohs.

The harvesting of green vegetables, as well as the knowledge linked with it, was a female field among both the Koisan and the Bantu-speaking tribes of South Africa (Van Rensburg *et al*., 2004). However, it was indicated by Van Averbeke and Juma (2006) that the existing evidence suggests that once a plant species is domesticated and grown as a crop, men get involved, particularly when its production is commercialized. Jew’s mallow is primarily picked from the wild in South Africa, but it has the potential to be developed as a commercial crop, especially in the country's northern and eastern regions (Van Rensburg *et al*., 2004). This plant germinates naturally in the study area especially towards the end of spring and flourishes throughout the summer.

2.2 Description of Jew’s mallow

Jew's mallow is an erect annual dicotyledonous herb that grows to a height of 20 cm to 1.5 m (Van Rensburg *et al*., 2007) and has pods, stems and leaves that differ in size, branching, and shape. It is a wild leafy vegetable often known as Jew's mallow or Wild jute (English), *Wild jute* (Afrikaans), *thelele* (Sesotho/Sepedi), and *ligusha* (Xitsonga) in different parts of South Africa (Van Rensburg *et al*., 2007). It is possible that the plant remains unbranched or has only a few side branches. The stems are angular, with alternate, simple, lanceolate leaves with a finely serrated or lobed edges and conspicuous hair-like teeth at the base (Nuwangburuka and Denton 2012; Smith, 2000). Insects pollinate the transsexual flowers. Flowers with five petals are tiny (2-3 cm in diameter) and yellow. Following bloom, the fruit is usually a multi-seeded straight, angular capsule that ranges in colour from green (immature) to brown (mature) (Matsufuji *et al*., 2001; Banerjee *et al*., 2012). The seeds are very small and differ from green to brown in colour. Jew’s mallow seeds have a high level of dormancy, which can be disrupted by several treatments, the most frequent being soaking them in hot water (Schippers *et al*., 2002).

2.3 Importance of *Corchorus olitorius*

Rural people use wild food as a safety mechanism to cope with food deficiency, catastrophe and livelihood strain (Cunningham, 1992). In addition, indigenous leafy vegetables are particularly important for Africans' diets because, by means of the prevailing livelihood practices in the region, they can easily be cultivated under severe environmental conditions. Indigenous leafy vegetables are simple to cultivate, even under difficult climatic conditions, and are tolerant to many pests and diseases (Cunningham, 1992).

Residents in remote rural communities where commercial vegetable growing is not practiced and market supply are not coordinated rely on indigenous leafy vegetables to supplement their diet diversity (Modi *et al*., 2006). As a result, popularizing and cultivating indigenous green vegetables is critical for creating jobs and ensuring that community members live better lives while also allowing disadvantaged farmers to produce food. In addition to having greater nutrient quality, *C. olitorius* grows more easily in rural subsistence farming systems than alien plants like cabbage and spinach (Modi *et al*., 2006). According to Oelofse and van Averbeke (2012), since it includes carotene and other carotenoids, vitamins B1, B2, C and E, and other essential minerals (Mavengahama *et al*., 2013), Jew's mallow is widely used as a health vegetable. The leaves of *C. olitorius* are believed to be emollient, diuretic, tonic and purifying to the human body (Fagbohoun and Ibrahim, 2011; Adebo *et al*., 2018). As a result of its sliminess, including *C. olitorius* in the preparation of coarse-textured indigenous vegetables like cowpea leaves, makes it easier for older people to consume the vegetables (Schippers *et al*., 2002).

2.4 Uses of *Corchorus olitorius*

The cultivated *Corchorus* species that are used as a main source of natural fibres mostly in Asian and Latin American countries are *C. olitorius* L. and *C. capsularis* L. (Ogunkanmi *et al*., 2010; Talukder *et al*., 2001). On the other hand, *C. capsularis* is not widely distributed in Africa, and *C. olitorius* is primarily grown as a vegetable crop (Talukder *et al*., 2001). The utilization of leafy greens is as old as modern man's history in South Africa (Van Rensburg *et al*., 2007). The practice of collecting these vegetables from the wild and planting them in the backyard gardens is still common among black South Africans (Van Rensburg *et al*., 2004; Husselman and Sizane, 2006; Modi *et al*., 2006).

Due to low-income levels of the bulk of the population in the Eastern Cape Province, wild vegetable consumption remains quite high (Vorster *et al*., 2002). Vorster *et al*. (2002) discovered that intake of wild-collected green vegetables is inversely linked to household income. The increased use of these vegetables by impoverished households in comparison to their wealthier counterparts is partly fuelled by a lack of financial resources to purchase exotic vegetables and the ability to grow their own (Vorster *et al*., 2002).

In the Eastern Cape Province, the use of wild vegetables continues to be relatively high owing to marginal socio-economic status of the majority of the rural population

(Vorster *et al.,* 2002). Vorster *et al.* (2002) quantitively recognized that the consumption of leafy vegetables collected from the wild tends to be inversely proportional to household income. The augmented use of these types of vegetables by poor households as compared to their wealthier counterparts is largely invigorated by the lack of financial means to purchase exotic vegetables and/or the ability to produce their own (Vorster *et al.,* 2002).

Zakaria *et al*. (2006) indicated that Jew's mallow is used in folklore medicine for gonorrhoea, chronic cystitis, pain, fever and turmors. Jew's mallow is recognized for having high quantities of iron (Fe), which is beneficial in preventing anemia (Oyedele *et al*., 2006). In the human nutrition, the leaves provide protein, energy, minerals, vitamins and certain hormone precursors (Antia *et al*., 2006). Various parts of *C. olitorius* are also employed in traditional medicine, including the seeds as a laxative, the leaves as a stomach pain reliever, the roots as a toothache treatment, and the stems as a cardiovascular problem treatment (Nemb *et al*., 2011). The edible leaves of the crop play an important economic role in the strategy to make rural and urban populations' food secure.

Fresh or dried leaves serve as a rich source of vitamins and minerals (Nemb *et al*., 2011) and are cooked into a dense slimy soup or added to stews or soups (Rashwan, 2011). According to Habib *et al*. (2015), the leaves are useful to make a sticky sauce that complements starchy food and are rich in amino acids and vital minerals. The leaves are also used as herbal pharmacopoeia against malaria or typhoid fever (Habib *et al*., 2015). In Kenya, root scrapings of *C. olitorius* are used to alleviate toothaches, whilst in Nigeria, purgative mixtures made from seeds are employed to relieve constipation (Ufoegbune *et al*., 2016).

2.5 Nutritional information

Jew's mallow is well-known for its significant role in the human nutrition, providing nutrients and making food more appetizing. It is critical to revitalize and demonstrate the utility and nutritional qualities of indigenous leafy vegetables like Jew's mallow in the larger context of national and regional food security in order to prevent the decline in the use of indigenous vegetables such as *Corchorus* and conserve knowledge (Loumerem and Alercia, 2016). The crop has been described to have demulcent, deobstruent, diuretic, lactagogue, purgative and tonic properties (Nemb *et al*., 2011).

As it contains carotene and other carotenoids, vitamins B1, B2, C and E, and minerals, Jew's mallow is often consumed as a health vegetable (Oelofse and van Averbeke, 2012). Earlier research indicated edible *Corchorus* species to be excellent suppliers of protein, vitamins (A, C, E) and mineral nutrients such as calcium (Ca) and iron (Steyn *et al*., 2001; Dansi *et al*., 2008). Jew's mallow is also known to have high quantities of iron and folate, which are beneficial in the prevention of anemia, according to Steyn *et al*. (2001).

In Africa and Asia, the nutritive value and micronutrient content of *C. olitorius* is alleged to have not been well researched. On average, *C. olitorius* contains 85-87 g water, 5.6 g protein, 0.7 g oil, 5.0 g carbohydrate, 1.5 g fiber, 250-266 mg calcium, 4.8 mg iron, 0.1 mg thiamine, 0.3 mg riboflavin, 1.5 mg nicotinamide, and 53-100 mg ascorbic acid per 100 g (Matsufuji *et al*., 2001; Ndlovu and Afolavan, 2008; Nemb *et al*., 2011). Jew's mallow leaves have a higher iron concentration than eggplant and spinach leaves (Nemb *et al*., 2011). Ndlovu and Afolayan (2008) evaluated the nutritional value of *C. olitorius* leaf against spinach and cabbage. They discovered that the magnesium (Mg) content of *C. olitorius* leaf was higher than that of spinach and cabbage, and that it also had more iron and zinc (Zn) than cabbage.

2.6 Mucilage content

Jew's mallow is well renowned and harvested in the tropics for its viscous or mucilage content contained in the leaves and tender stems. Mucilage of *C. olitorius*, as stated by Tsukui *et al*. (2004), is an acidic polysaccharide composed of galacturonic acid, galactose, mannose, glucose and arabinose. The leaves of the crop are viscous or slimy, and as such are savored by those who eat the plant owing to the presence of this mucilaginous polysaccharide. In addition, the mucilaginous polysaccharide in the leaves contains rhamnose, galactose, glucose, galacturonic acid and glucuronic acid, and is high in uronic acid (65%) (Adediran *et al*., 2015). The ability of the leaves to produce mucilage is valued in the generation of sources that can be combined with starchy foods (Ngomuo *et al*., 2017). When cooked, *Corchorus* has a similar mucilaginous texture as okra (*Abelmoschus esculentus*) (Van Rensburg *et al*., 2007). People in the northern parts of South Africa enjoy the sliminess of the crop more (Van Rensburg *et al*., 2007). To decrease the sliminess of *Corchorus*, folks in the southern regions add bicarbonate of soda or even cow urine to the cooking water (Van Wyk and

Gericke, 2000; Schippers *et al*., 2002). In Zimbabwe, many rural communities use wood ash as a substitute for bicarbonate of soda.

2.7 Climatic requirements

2.7.1 Temperature and humidity

Jew's mallow has been known to naturally germinate from seeds and to grow in a variety of soils and climates (Oladiran, 1986). According to Van Rensburg *et al*. (2007), the crop has evolved to favour warm, humid environments, as evidenced by its occurrence primarily in South Africa's northern and eastern regions in which such conditions are prevalent. This is also affirmed by Van Wyk and Gericke (2000) who stated that *C. olitorius* enjoys warm, humid environments and thrives in places with high temperatures (30°C during the day and 25°C at night). Consequently, the crop is familiar in the northern and eastern parts of South Africa where such conditions are prevalent. Growth of Jew’s mallow reduces substantially when the temperatures drop below 15°C (Van Rensburg *et al*., 2007). This was further corroborated by Bamigboye (2011) who maintained that temperatures below 8°C or over 40°C may result in cessation of Jew's mallow crop development.

Tsimba *et al*. (2013) declared that crop losses and yield reduction in Africa is as a result of extremes in environmental factors in a maize study. Studies on effects of planting dates on crop growth and development reported that temperature is the most important environmental factor influencing success or failure of the cropping season (Tsimba *et al*., 2013). Rashwan (2011) specified that temperature is undoubtedly acknowledged to affect growth and development processes of the plant, but optimum atmospheric temperature varies with processes the crop undergoes.

2.7.2 Rainfall

Despite the crop's nutritional value, production is restricted to the wet season due to a lack of water throughout the dry season. Due to its short root depth, the crop is sensitive to moisture stress, which can be avoided by employing irrigation (Fasinmirin and Olufayo, 2009). Earlier studies by Ayodele and Fawusi (1989 and 1990) reported that *C. olitorius* is susceptible to moisture stress at both vegetative and reproductive stages of growth. Jew’s mallow performs well in high rainfall areas Van Wyk and

Gericke (2000) and its growth is considerably slowed down when it is subjected to a prolonged period of water deficit (Van Rensburg *et al*., 2007). The crop is widely grown in dry or semi-arid areas, characterised by low and poorly distributed rainfall and short growing seasons.

Agricultural productivity is believed to be under threat due to global climate change. This threat is more imminent in developing and underdeveloped countries, particularly in rural communities. According to Davis (2008), climate change resulting in extreme heat, floods and drought is posing challenges to agriculture as a source of livelihood. The vulnerability to climate change comes both from being located mainly in the tropics, and from the various socioeconomic, demographic and policy trends limiting their capacity to adapt to the changes. South Africa, being part of the Southern African community, is not unique; the majority of the poor (72%) are situated in such areas where they depend on dryland farming (Ortmann and Machete. 2003).

According to Davis (2008), challenges in subsistence farming are imposed by the perpetual risk caused by seasonal variability of rainfall through both uneven distribution and variable precipitation quantities in South Africa. The choice of planting date and crop to grow becomes a challenge to the subsistence farmer. Some farmers split or stagger planting within one season to avoid absolute risk of crop failure (Traore *et al*. 2007, Lemos and Dilling 2007). Climate change is affecting rainfall patterns, which has an impact on forecasting. The change in planting dates also means that some crops that farmers have traditionally grown may no longer be suitable for the new season periods. As a result, there is a need to diversify subsistence farmers' crop base to promote on-farm agro-biodiversity and resilience.

2.7.3 Edaphic requirements

When compared to exotic crops like cabbage and spinach, Jew's mallow grows easily in rural subsistence farming (Modi *et al*., 2006). It is frequently found around swamps or wet places near rivers and lakes in its natural habitat throughout tropical Africa (Bamigboye, 2011). Jew's mallow favours light-sandy, medium-loamy, and heavy-clay soils according to Olanrewaju and Nwangburuka (2012). It was further stated that the crop cannot grow in shaded areas and requires moist soil. According to (DAFF, 2012), the crop is considered a low-maintenance crop because it can thrive on poor soils and in regions where the environment is not favourable to exotic vegetable growing. Jew's mallow grows best in rich, well-drained, medium-textured soils, but it can also grow in coarse and fine-textured soils (Bamigboye, 2011). As a result, the main idea is that when suitable agronomic management parameters such as planting period are set, the crop would grow better and provide larger yields.

2.7.4 Plant protection

Since pests are typically abundant and attack the crop at specific times, planting period management has a significant impact not only on crop growth, development, and yield, but also on insect pest management (Kanase *et al*., 2018). Traditional green vegetables, such as Jew's mallow, have been shown to be pest and disease resistant (DAFF, 2012). Leaf-eating grasshoppers, caterpillars, and the armyworm are all major pests of *Corchorus*. The *Meloidogyne* species nematode infestation can drastically lower yields and result in plant death, although pure poultry droppings have been proven to be effective in controlling it (Samra *et al*., 2007). Cutworms, which feed on the stem bases of immature seedlings, can cause significant harm. The crop is not particularly susceptible to disease; collar rot and black leaf spot have been observed sometimes (Shiwachi *et al*., 2008). According to Kanase *et al*. (2018), transplanting timing has a significant impact on crop yield, as delayed transplanting reduces yield by halting plant growth and causing production blindness owing to insect-pest assault. Early planting provides the advantage of better market circumstances, but it has the downside of increasing the incidence of pests, as reported by small holder farmers in Limpopo (Ndlovu and Afolavan, 2008).

2.8 Potential contribution of *C. olitorius* to food security

The quantity of iron, protein, calcium, thiamine, riboflavin, niacin, folate, and dietary fibre found in Jew's mallow and other African leafy vegetables (ALVs) has the potential to alleviate micronutrient deficiencies (Leung *et al*., 1968). This crop supplies food for rural households, with surpluses being sold to urban markets to generate income (DAFF, 2012). According to studies, African leafy vegetables such as *C. olitorius* have the potential to generate cash for small-scale farmers and anyone involved in the economic activities associated with their production (Weinberger and Pichop, 2009). However, in South Africa, income generation from the sale of ALVs is still modest, and primarily limited to dried commodities (Hart and Voster, 2006). In South African informal marketplaces, *Amaranthus cruentus* and *C. olitorius* are being sold as leafy greens (Weinberger and Pichop, 2009). These plants are collected as weeds from fields and vegetable gardens by street sellers.

Jew's mallow has the capacity to be a common crop for disadvantaged people who live in remote places and practice low-input farming. Despite its abundance, it is underutilized just like other ALVs. This is influenced by a variety of factors, including perception, processing, distribution and marketing, as well as nutritional information (Shiundu and Oniang'o, 2007). Water shortages and population increase are also a challenge in South Africa (Mabhaudhi *et al*., 2013). Incorporating ALVs into cropping systems can help poor rural communities adapt to climate change, protect the environment and provide jobs (Mabhaudhi *et al*., 2016). This would be especially advantageous to underprivileged rural people that are unable to financially afford exotic vegetables. Most smallholder societies live in rural locations where crops struggle to thrive and water scarcity is a problem. African leafy vegetables provide an alternative to such communities since they can withstand abiotic conditions like drought and heat (Oelofse and van Averbeke, 2012).

2.9 Crop responses

2.9.1 Crop response to planting date selection

One of the most vital aspects in production of any crop is the appropriate sowing date when it is cultivated, and Jew’s mallow is no exception. According to Seghatoleslami *et al*. (2013), an optimum sowing date for a crop is when the plants are fully established, and their vulnerable growth periods do not overlap with severe environmental conditions. Knowing the best sowing date would help the grower maximize yield. The choice of planting dates could significantly impact on growth and yields of crops, particularly during the critical development phases where plants require adequate moisture and ideal temperatures at planting, seedling establishment, flowering and fruit formation (Passioura, 2007). Poor planting date selection may subject crops to water and heat stress during dry spells at critical growth stages resulting in reduced yield. To minimize farming risk, a need arises to ascertain planting dates and good crop choices among subsistence farmers. As temperature, solar radiation, photoperiod and rainfall fluctuate randomly around seasonal average tendencies, the greatest challenge is adjusting the ideal time for planting (Tsimba *et* *al*., 2013). Climatic change makes appropriate positioning of planting time vital to maximizing crop yield (Laux *et al*., 2010; Folberth *et al*., 2012) and its negative impact can be reduced by adapting to new climatic scenarios (Waha *et al*., 2013).

2.9.2 Plant growth and development

Anjum *et al*. (2011) defined plant growth is defined as the irrevocable rise in mass that occurs from cell division and cell expansion. Studies by Nonami (1998) stated that meristematic cell divisions give rise to daughter cells which result in growth through the multiplication of many young cells. It is the level of mitosis that determines plant growth and yield (Anjum *et al*., 2011) which is why the process is important to understand where growth and yield are of concern. Furthermore, development is the sum of all changes that the plant goes through in its life cycle. Plant growth and development are controlled by three factors which are genetic control, hormonal control and lastly environmental stimuli (Xiong *et al*., 2006). Cultivation procedures such as planting date should be known with great precision because they have an impact on a vegetable's quality, growth, and production.

When planting *amaranthus* for example, it is necessary to attain an early yield and subsequently a high price which assures high returns for the producers (Yarnia, 2010). On the contrary, there is an adamant risk of exposing undeveloped crops to cool climate after field setting which will result in environmental stress. There is an ideal temperature at which a plant grows rapidly for each species, while lower non-freezing temperatures allow development but at a somewhat slower rate. Furthermore, Nam *et al*. (1995) found that when plants are exposed to extreme temperatures, several physiological and biochemical processes are altered, resulting in alterations in chemical composition. The severity of these alterations is mostly determined on the temperature, the time of exposure to the temperature, and the stage of plant development (Yarnia, 2010).

Planting date may affect the growth and development of Jew's mallow from germination and emergence stages like it does to other African indigenous summer crops such as cowpea. Cowpea has been reported to have a slow and partial emergence due to different planting dates (Ismail *et al*., 1997). Sowing cowpeas too early and at temperatures below 19°C has been documented to produce chilling damage, resulting in sluggish and partial emergence (Ismail *et al*., 1997). Planting dates that are too late, poor stand establishment, and dryness have all been recognized as factors that limit legume growth (Sullivan, 2003). Seedling emergence and establishment are critical stages in crop production which when plants are subjected to either extremely low temperatures, germination may be delayed, or extremely high temperatures seedling mortality can occur due to seedbed dryness caused by too much heat (Oelofse and van Averbeke, 2012).

Planting dates should be chosen to avoid climatic elements that cause stress to plants during the growing period. Changes in temperature and day duration during the growing season are linked to plant height reduction caused by delayed planting (Barros *et al*., 2004). Plant height in *amaranthus* has been found to be reduced as a result of planting delays (Yarnia, 2010). Delay in planting was reported to cause plant height reduction in *amaranthus* (Yarnia, 2010). A study on groundnut showed that generally, plant height decreases with delayed planting (Sajo and Mohammed, 2004). Planting time significantly affects number leaves and plant height (Ullah *et al*., 2013). Tesfaye *et al.* (2018) observed significant difference on plant height and number of leaves as affected by planting time and argued that taller plants with a higher number of leaves have a higher photosynthetic capacity than those with a shorter height and fewer leaves. There is a direct relationship between number of leaves per plant and temperature (Adil *et al*., 2013). Reduced day and night average temperatures that dominate during vegetative growth, according to Kanase *et al*. (2018), can lead to small stem girth.

2.9.3 Stomatal conductance and chlorophyll content

Plants that are grown in such a way that their developmental phases correspond with inadequate moisture levels, drought stress and high temperature will close their stomata to prevent water losses. As a result, the flow of CO_2 into the leaves will decrease, resulting in a drop in photosynthetic efficiency (Modi and Mbahudhi, 2013). Stomata appear to play a role in limiting the outward flux of water vapour from the leaf while allowing minimum CO_2 inward diffusion to support photosynthesis. If stomata are not properly open in any setting, photosynthetic production will drop. When stomata open too widely, water is squandered (Raschke, 1979). Because the two processes of photosynthesis and transpiration do not always respond in lockstep to changes in environmental variables, controlling stomatal opening is difficult.

Environmental parameters such as light intensity, temperature and CO_2 concentration all influence the potential rate of photosynthesis. Leaf temperature, air humidity and wind speed all affect potential transpiration (Zeiger, 1983). Stomata appear to respond to four environmental variables to fulfil their daily duty: light, carbon dioxide, temperature and humidity. Responses to additional elements such as hormones and the plant's nutritional status become vital over time periods greater than a day (Modi and Mbahudhi, 2013).

The level of chlorophyll in plants maintains their photosynthetic potential (Jiang and Huang, 2001). El-Khoby (2004) found that delaying sowing reduces the amount of chlorophyll in crops. Biswas *et al*. (2002) reported that the increase in leaf photosynthetic rate was accompanied by an increase in stomatal conductance in a study on the effect of four planting dates on beans. Adil *et al*. (2013) found a significant positive relationship between temperature and chlorophyll content on gladiolus and went on to say that chlorophyll content is one of the most crucial criteria for determining plant health because it directly relates to physiological activities that produce food. At high temperatures, they also observed an increase in chlorophyll and photosynthetic activity.

2.9.4 Yield

When it comes to getting a great harvest, sowing and transplanting at the right times are crucial (Yoldas and Esiyok, 2004). Earlier research has shown that increased temperatures have an impact on agricultural productivity, which is often impacted by planting date (Hall, 1992). To produce maximum yields in any planted crop, the best planting date must undoubtedly be determined. According to a study by Yarnia (2010), optimizing growth duration and seed maturation results in maximum yields as well as a reduction in unfavourable environmental conditions on grain and forage quality.

Yarmia (2010) went on to say that if the right planting date is chosen, a cultivar with a long enough growth period can flower and yield seeds on time. If a plant blooms too early, it will not provide the maximum yield. Furthermore, early sowing can raise the chance of late freezing. Yarnia (2010) stated that early planting date boosted amaranth leaf area length and water absorption during the key period between flower bud appearances and flowering. According to Green *et al*. (1985) planting timings can differ and be inconsistent between seasons and places, and it is not uncommon for late planted crops to out-yield the optimum planting. Schippers (2000) mentioned that C4 plants such as Jew's mallow thrive in warm environments (day temperatures over 25 °C and night temperatures not below 15 °C), strong light, and enough nutrition availability.

A study on Amaranth has shown that the crop has high sensitivity to photoperiodism and begins to blossom as soon as the day duration shortens (Yarnia, 2010). Tesfaye *et al*. (2018) detailed that high temperatures during flowering cause floral abortion, which leads to poor seed output. Incredibly low temperatures, foggy weather and rain during the flowering season, on the other hand, disrupt bee movement and the pollination process. In support, Akter *et al*. (2017) affirmed that planting time has a significant effect on light intensity, photoperiod, day and night temperature, and hence may affect flower initiation, fruiting, yield and quality of crops. Number of days to 50% flowering is shorten with delayed planting (Sajo and Mohammed, 2004). According to Sajo and Mohammed (2004), temperature, light duration and other stress conditions in the soil such as nutrient and moisture deficiencies influence flowering date. As a result, crops planted even on the same dates in different years, may have different flowering dates. Longer time to flowering is required in lettuce when the planting occurs early (Firoz *et al*., 2009).

Adil *et al*. (2013) cited that dry matter production increases at high temperatures, which they ascribe to the crop's vegetative sections accumulating more photosynthates. Earlier findings by Zhao *et al*. (2006) detailed that plant growth contributes wholly to the increase of fresh and dry matter. In the fresh leaf yield of Chinese cabbage, the planting date has been reported to be the most important yield element (Juma *et al*., 2005). According Ullah *et al*. (2013), different planting time affect weight of plants. In addition, they mentioned that optimum planting time ensures proper growth of plant and consequently the highest plant weight.

Seed is one of the most essential factors affecting the crop's productivity. When compared to ordinary seeds, it is believed that using superior quality seed can enhance productivity by 15 to 20% (Bera *et al*., 2010). Effective adjustments of yield attributing features that have a favourable influence to seed yield can boost the potential of the Jew’s mallow crop. (Talukder, 2001). The period in which the plant has been planted may well be one of the major contributing factors to *C. olitorius* seed yield.

CHAPTER 3

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Description of the study area

The two trials were carried out simultaneously, the first trial was on the field and the second (pot trial) in the shade house during the 2018/2019 summer growing season. The field is located at 23°88'60"S, 29°73'85"E, while the shade house is located at 23°53'10"S, 29°44'15"E. The two research locations were at the University of Limpopo, Mankweng area in Limpopo Province, South Africa.

Mankweng gets about 403 mm of rain each year on average, with most of it during summer. Mankweng's average noon temperatures range from 18.9°C in June to 26.1°C in January. The coldest month in the region is July, when the average night-time temperature dips to 3.6°C. Summers are hot and dry, with daily maximum temperatures ranging from 28°C to 38°C (Scheoman *et al.,* 2015). Climatologically, Mankweng area falls in the semi-arid tract with a summer rainy season and a pronounced dry spell during winter.

3.2 Land preparation and pre-planting soil sample

The field for the field trial was prepared with hand hoes, spade and harrowed with garden fork and rake to raise the seedbeds. The area was cleared of weed trash, stubbles and clods to obtain a fine tilth. The field was then divided into required number of plots which were thoroughly irrigated and allowed to rest for a day before transplanting the seedlings. The seedlings were then transplanted in the field at intra and inter row spacings of 0.3 m × 0.3 m, respectively. For the pot trial in the shade house, crops were planted in 24 cm pots filled with topsoil as growing medium obtained from the University of Limpopo experimental farm (Syferkuil farm). The pots were separated by 0.3 m x 0.3 m and containing three plants each.

Soil analysis was done from soil samples obtained from research location to get fine details about the soil properties; soil texture (Bouyoucos hydrometer method), pH (Glass electrode method), electrical conductivity (digital conductivity meter), soil organic carbon (Walkley and Black method), total nitrogen (N) and phosphorus (P) (spectrophotometric method). A total of 27 composite soil samples (0-30 and 30-60 cm depth) were collected at random with a soil auger, air dried at room temperature, sieved through a 2 mm sieve, and analysed at CEDARA laboratory for physical and physico-chemical properties; bulk density, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), exchangeable acidity, total cations, acid saturation, pH, zinc (Zn), manganese (Mn), copper (Cu), clay percentage, Nitrogen (N) and organic carbon (OC). Based on the result of the soil analysis from study locations, Lime Ammonium Nitrate (LAN-28% N) was applied at two and six weeks after transplanting (WAT) at the rate of 30 kg N/ha.

3.3 Planting of the trial and sources of planting materials

Seeds of *C. olitorius* (cultivar 'Local') (Figure 3.1) were obtained from Venda area, Limpopo Province in South Africa, while the two other cultivars 'Amugbadu' (Figure 3.2) and 'Oniyaya' (Figure 3.3) were obtained from National Horticultural Research Institute (NIHORT) in Nigeria. The seeds were wrapped in a soft cotton cloth and soaked in hot water (70-80°C) for five minutes; (water that had been boiled and allowed to cool for two minutes before soaking) to break seed dormancy and improve germination. Seeds were then sun dried for about 24 hours. Commercial growing medium, Hygromix® (Hygrotech Seed Pty. Ltd., South Africa) was moistened and filled in 200 cavity polystyrene trays in which two seeds per cavity were sown at a depth of 0.5 cm resulting in 400 seeds per tray (Figure 3.4). The sown seeds were kept in a shade house until they germinated, emerged and were ready for transplanting (exactly six weeks after sowing and at about 8-12 cm height).

Figure 3.1: Jew’s mallow test crop, ‘Local’ cultivar planted in the field

Figure 3.2: Jew’s mallow test crop, ‘Amugbadu’ cultivar planted in the field

Figure 3.3: Jew’s mallow test crop, ‘Oniyaya’ cultivar planted in the field

Light irrigation was applied before and immediately after transplanting to ensure proper germination and plant stand. The seedlings were transplanted in irrigated plots and adequate water, an estimate of 50-80 mm was applied soon after transplanting to minimise transplanting shock. Subsequent irrigations were provided as and when required throughout the duration of the experiment, on average after every other two days. Weeds were monitored and removed manually using hands whenever they appeared in the trials. Incidence of cutworms (*Agrotis ipsilon*) were observed twice (at five days after transplanting and at five weeks after transplanting) during growth period and were immediately controlled. Soon after transplanting, cutworm bait (Sodium Fluosilicate 100 g/kg) was applied around the stems of the seedlings by sprinkling 100g of the pesticide granules evenly per square meter to control cutworms and repeated when damage was observed.

Figure 3.4: Jew’s mallow seedlings in polystyrene trays at 3 weeks after sowing

3.4 Experimental design, treatments and procedures

Treatment combination of two growing conditions (Field and pot), four transplanting periods (November, December, January and February) and three cultivars (Local, ‘Oniyaya’ and ‘Amugbadu’) was laid out as a 2 x 4 x 3 split-spilt plot arrangement in a randomized complete block design with three replications. For transplanting, seeds were sown in the seedling trays in early October, November, December, January and transplanted mid-November, December, January and February, respectively. Hence the term planting period used. Growing conditions (environment) was assigned the main factor, planting period as the sub-factor, whilst the cultivars constituted the sub-subplot factor. In the field, each experimental unit was 2 m x 1 m in size. Each block of the field experiment had 12 units, three subplots per each of the four planting periods. There was a 1 m space between the main plots, 1 m between the sub plot and 0.5 m between the sub-sub plots to allow free movement during cultural practices. For the pot trial (three plants per pot), seedlings were transplanted at a spacing of 0.50 m by 0.50 m, with three replicates.

3.5 Data collection

A total of three randomly selected plants per sub-plot and two plants per pot were selected and labelled for continuous record of growth and yield parameters. The below mentioned parameters were measured at six weeks after transplanting (WAT) and from there after every two weeks (fortnightly) until maturity. Plant height (cm) was measured from base of the plant stem to the apex using a meter ruler. The number of days to crop emergence and stand establishment (at six weeks after transplanting and at final harvest) were counted. Number of fully expanded leaves per plant was counted and leaf area (cm^2) was measured from the biggest three leaves per plant using a leaf area meter (AM350) model.

Stem diameter (mm) was measured from the base of plant stem using a 150 mm digital vernier caliper. The number of branches per selected plant was also counted and chlorophyll content (cci) measured from randomly selected fully expanded outer and top leaves in the tree canopy using a CCM-200 chlorophyll meter. Plant biomass (g) (both below ground and above ground biomass) was determined at six weeks after transplanting and at final harvest using a weighing scale. Fresh and dry weight (g) (dried at 65 ^{o}C to a constant weight in an oven) of both shoots and roots were determined using a weighing scale (Figure 3.5).

Plants harvested at 6 WAT were analysed for nutrient elements at CEDARA and at the University of Limpopo laboratories (Figure 3.6 and 3.7). To quantify Iron (Fe), Nitrogen (N), Calcium (Ca), Magnesium (Mg), Potassium (K), Copper (Cu), Manganese (Mn), Phosphorus (P), Aluminium (Al), Sodium (Na), Zinc (Zn), dry matter and ash, dried mature leaves and small stem branches were ground in a Wiley mill and passed through a 0.5 mm sieve. The resulting 20 g measurable fine powder was then stored in 6.5 cm x 8 cm resealable plastic bags.

The number of days to flowering and 50% flowering, pod formation and pod maturity were observed and recorded, together with the number of pods per plant at final harvest. Pod weight and seed yield were obtained by weighing pods and seeds after harvest. Weather conditions and climatic information (rainfall, relative humidity, wind speed, sunshine hours and temperature) was obtained from South African Weather Service (SAWS) throughout the growing season. The temperature in the shade house was recorded twice a day during the growing season using a thermometer. Photosynthetically active radiation (PAR) and stomatal conductance (gs) were measured using portable plant photosynthesis meter (LI-6400XT model) at 6,8 and 12 WAT in both growing conditions. Furthermore, the plant mucilage was obtained from harvested stems and leaves (as viscous flow water) and measured using a viscometer (NDJ digital viscometer model) (Shiwachi *et al*., 2008) at 6 and 8 WAT.

N.B. Both PAR and (gs) data was incomplete due to technical challenges that occurred with portable plant photosynthesis meter, its availability and lack of funds to find a replacement in time. As a result, the results were deemed unreliable and not included in the mini-dissertation.

Figure 3.5: Determination of *C. olitorius* fresh biomass (g) at 6 weeks after transplanting using weighing scale

Figure 3.6: Oven dried powder of ground leaves of *C. olitorius* harvested at 6 weeks after transplanting for determination of ash content

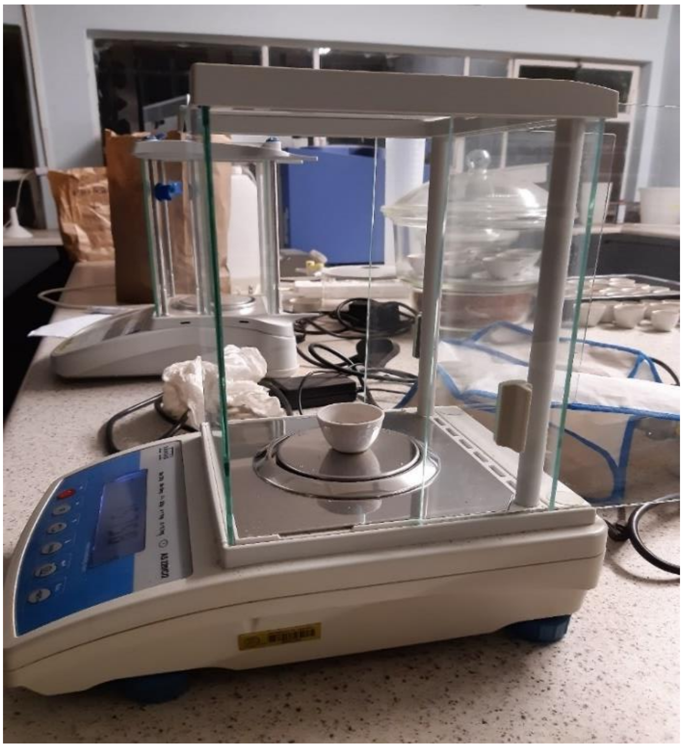


Figure 3.7: Oven dried powder of ground leaves of *C. olitorius* on a weighing scale, harvested at 6 weeks after transplanting for dry matter determination

3.5.1 Experimental soil properties data in Mankweng during growing season

The experimental topsoil and subsoil were generally slightly acidic, contained average bulk density, nitrogen, and clay percentage while it is slightly high organic carbon. The soil contained nutrient elements which were below the critical levels (Law-Ogbomo and Osaigbovo, 2016). The pH of the soil used in pot trail was more neutral and had low mg/L of P, K and Ca although mg/L of Mg was more than twice as high compared to field soil. The soil further contained marginally higher percentage of clay but lower levels of Zn, Mn, Cu, organic carbon and nitrogen (Table 3.1). As a result, the fertility status of the soil was low. This characterisation agreed with Akanbi *et al*. (2011) who suggested that most African soils are of a poor fertility status because of erosion, leaching and rigorous cultivation. The resultant implication is that reasonable crop yield cannot be attained without soil adjustment. The soil form at the study area was predominantly Hutton and the soil type was characterized as sandy loam with the following analytical results:

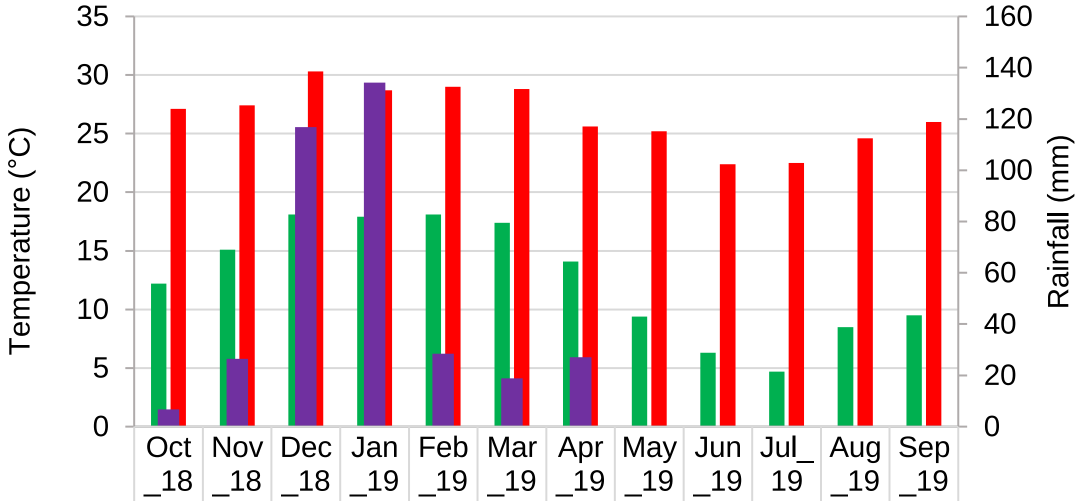
Table 3.1: Soil analytical results in the study area before crop establishment

Soil properties	Field trial		Pot trial	Method
	0-30 cm	30-60 cm		
Bulk density (g/mL)	1.43	1.42	1.33	Intact core method
P (mg/L)	100.58	108.50	51.00	Extractable (1 M Ambic-2)
K (mg/L)	214.58	221.50	177.33	Extractable (1 M Ambic-2)
Ca (mg/L)	1091.50	1058.58	769.00	Extractable (1 M KCl)
Mg (mg/L)	165.67	150.17	526.33	Extractable (1 M KCl)
Exch. acidity (cmol/L)	0.08	0.06	0.04	Differential titration
Total cations (cmol/L)	7.44	7.14	8.66	Extractable (1 M KCl)
Acid sat. (%)	1.00	1.00	0.00	Differential titration
pH (KCl)	5.10	5.15	7.20	KCl
Zn (mg/L)	29.49	29.47	0.47	Extractable (1 M Ambic-2)
Mn (mg/L)	24.58	23.92	9.67	Extractable (1 M Ambic-2)
Cu (mg/L)	12.65	13.53	2.37	Extractable (1 M Ambic-2)
Org. C (%)	1.57	1.79	<0.5	Walkley-Black
N (%)	0.08	0.10	<0.05	Automated Dumas
Clay (%)	17.33	17.92	19.67	Near-infrared spectroscopy
Silt (%)	14.00	14.00	15.00	Near-infrared spectroscopy
Sand (%)	68.67	68.08	65.33	Near-infrared spectroscopy
Textural class	Sandy loam	Sandy loam	Sandy clay loam	Textural triangle

3.5.2 Meteorological data in Mankweng during 2018/2019 growing season

The monthly mean minimum and maximum temperatures ranged from 4.7 °C to 18.1 °C and 22.4 °C to 30.3 °C respectively, with average minimum and maximum temperatures of 12.6 °C and 26.5 °C, respectively. The monthly mean relative humidity ranged from 38.7% to 67.7%. A total rainfall of 355.3 mm was received during the period of experimentation. The average monthly sunshine hours were recorded to range from 7.1 hours to 10.2 hours, with average minimum and maximum wind speed of 2.0 m/s and 4.4 m/s, respectively throughout the experiment period (Figures 3.8, 3.9 and 3.10). Jew's mallow is generally suited for such environmental conditions. The average minimum and maximum temperatures in the shade house were recorded to be 15.3 and 27.92, respectively (Figure 3.11).

Data pertaining to climatic conditions in Mankweng over the growing period is depicted graphically in Figs. 3.5 to 3.8



	Oct _18	Nov _18	Dec _18	Jan _19	Feb _19	Mar _19	Apr _19	May _19	Jun _19	Jul_ 19	Aug _19	Sep _19
Min Temp,	12	15	18	18	18	17	14	9	6	5	9	10
Max Temp,	27	27	30	29	29	29	26	25	22	23	25	26
Rainfall	7	27	117	134	28	19	27	0	0	0	0	0

Figure 3.8: Average monthly temperatures (minimum and maximum) (^{o}C) and rainfall (mm) in Mankweng during 2018/2019 planting season (SAWS, 2019), Polokwane station records

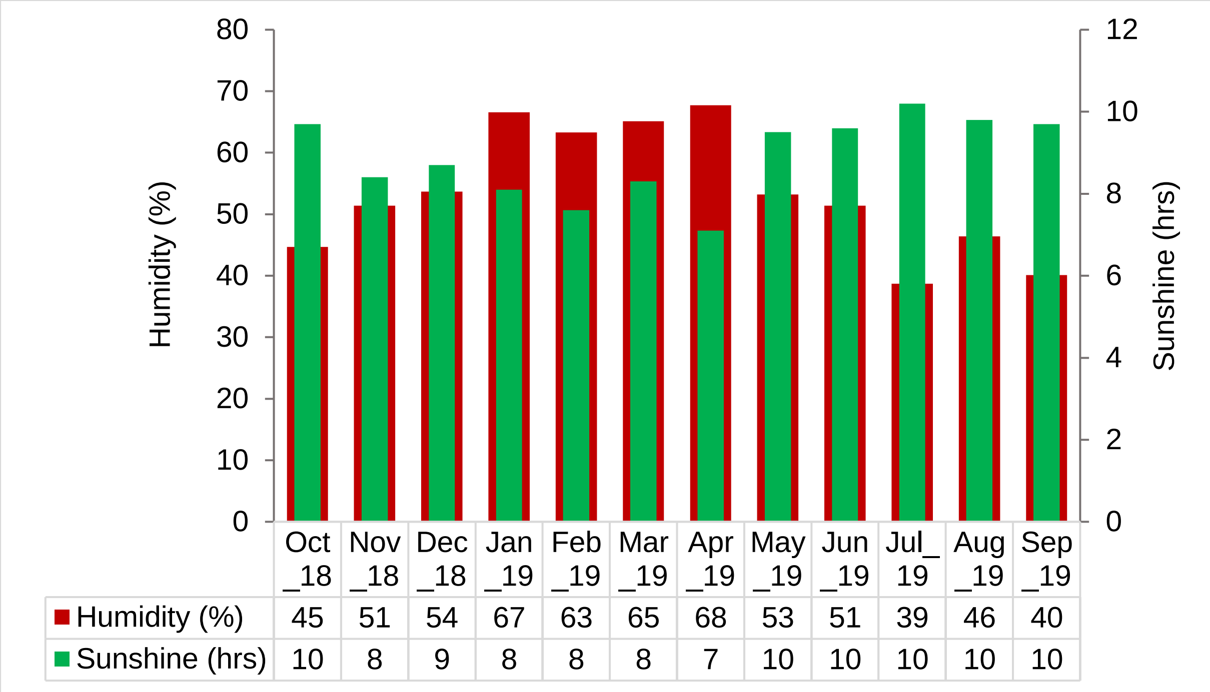


Figure 3.9: Average monthly humidity (%) and sunshine hours in Mankweng during 2018/2019 planting season (SAWS, 2019), Polokwane station records

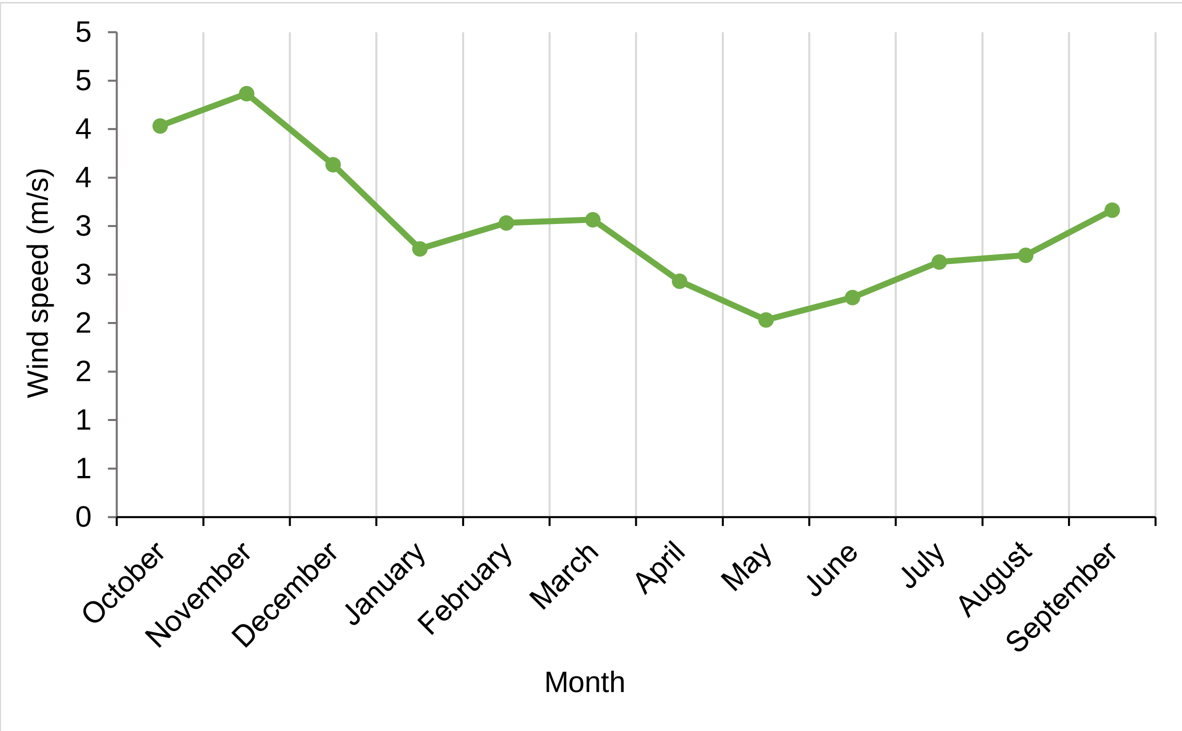


Figure 3.10: Wind speed pattern (m/s) in Mankweng during 2018/2019 planting season (SAWS, 2019), Polokwane station records

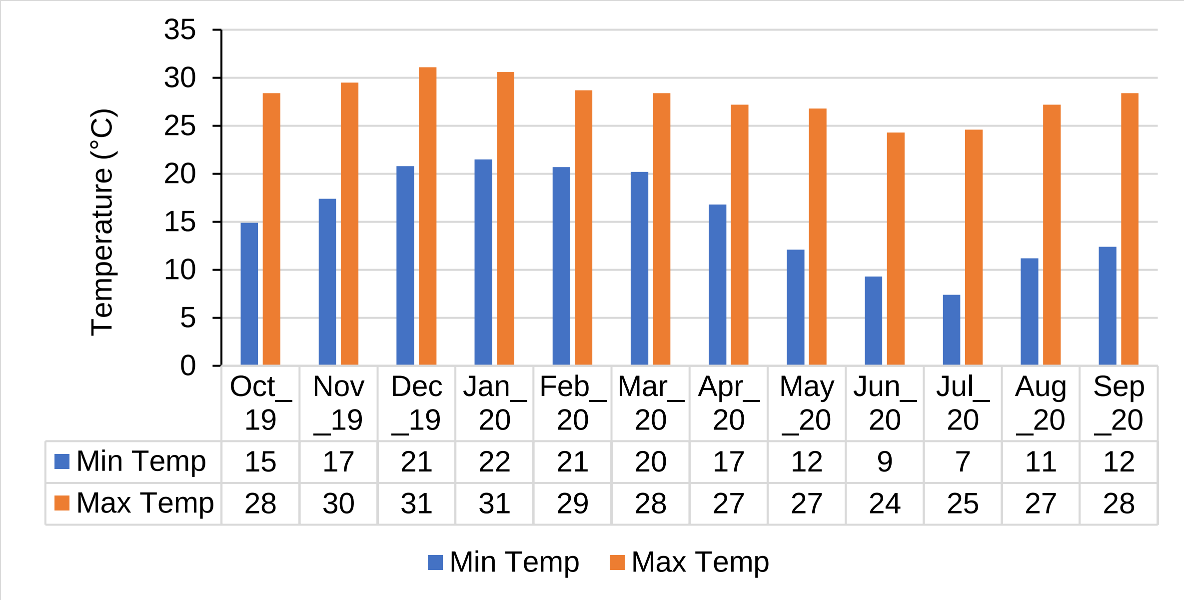


Figure 3.11: Average monthly temperatures (minimum and maximum) (^{o}C) in the shade house of the Department of Plant Production, Soil Science and Agricultural Engineering during 2019/2020

3.6 Data analysis

The generated data were subjected to analysis of variance (ANOVA) using Statistix 10.0 version. Means were separated using the Tukey HSD at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Effect of planting period and cultivar on seed germination, emergence and crop population stand establishment

Seed germination and seedling emergence of the three cultivars of *C. olitorius* varied with sowing period. Seed germination signifies crop emergence percentage and seed dormancy was similar across all cultivars which resulted in similar germination and emergence pattern. Seedling emergence and temperature during the period are presented in Figure 4.1 and Table 4.1. In this study on *C. olitorius* germinability, number of days to seedling emergence was approximately the same in November, December and January across all cultivars, an average of three days from the day 01 to 50% seedling emergence. There was little variation in the time required for the crop to reach 50% emergence, but the crops planted in October took a little longer to emerge than other sowing dates (Figure 4.1), with the Local cultivar emerging ahead of the two exotic ones. Jew's mallow is a heat demanding crop and generally requires high atmospheric temperature across all growth stages. According to research findings, such temperatures are also required during germination and emergence (Denton *et al*., 2013; Mguis *et al*., 2014).

An average maximum temperature of +/- 30°C is required for optimum emergence of *C. olitorius* (Ibrahim *et al*., 2013; Mguis *et al*., 2014), and this average temperature was experienced within the 7 days after seed sowing in November, December and January, yet considerably lower average temperature (23.53°C) was experienced in in October (Table 4.1). The delayed seedling emergence in October may be linked to low temperatures experienced during seedling emergence, which was below optimum for the crop. Jew's mallow naturally grows well mostly when day temperatures average 30°C. The findings from this study agree with those of Mguis *et al*. (2014) who reported that germination was depressed by a reduction or upsurge in temperature from the optimum.

Initial and final population stand was recorded to assess whether the crop population as per treatment combination was maintained. There was no significant ($P \leq 0.05$) interaction between cultivar, planting period and growing condition on *C. olitorius* stand establishment of at 6 WAT (initial crop population stand) (Appendix 4.1) and 18 WAT (final crop population stand) (Appendix 4.2). Similarly, interaction between cultivar and planting period; cultivar and growing condition; and planting period and growing condition had no significant effect on stand establishment. Furthermore, stand establishment did not differ significantly ($P \leq 0.05$) among the cultivars. Planting period also had no significant ($P \leq 0.05$) effect on population stand (Appendix 4.1 and 4.2). This suggests that the conditions across all planting periods were good for establishment of selected cultivars of *C. olitorius* tested. This contradicted Sullivan (2003) who reported delayed planting as a limiting factor in relation to good plant population stand establishment. According to Mguis *et al*. (2014), not only planting time can affect population stand but also many other factors such as temperature, soil borne diseases and water stress.

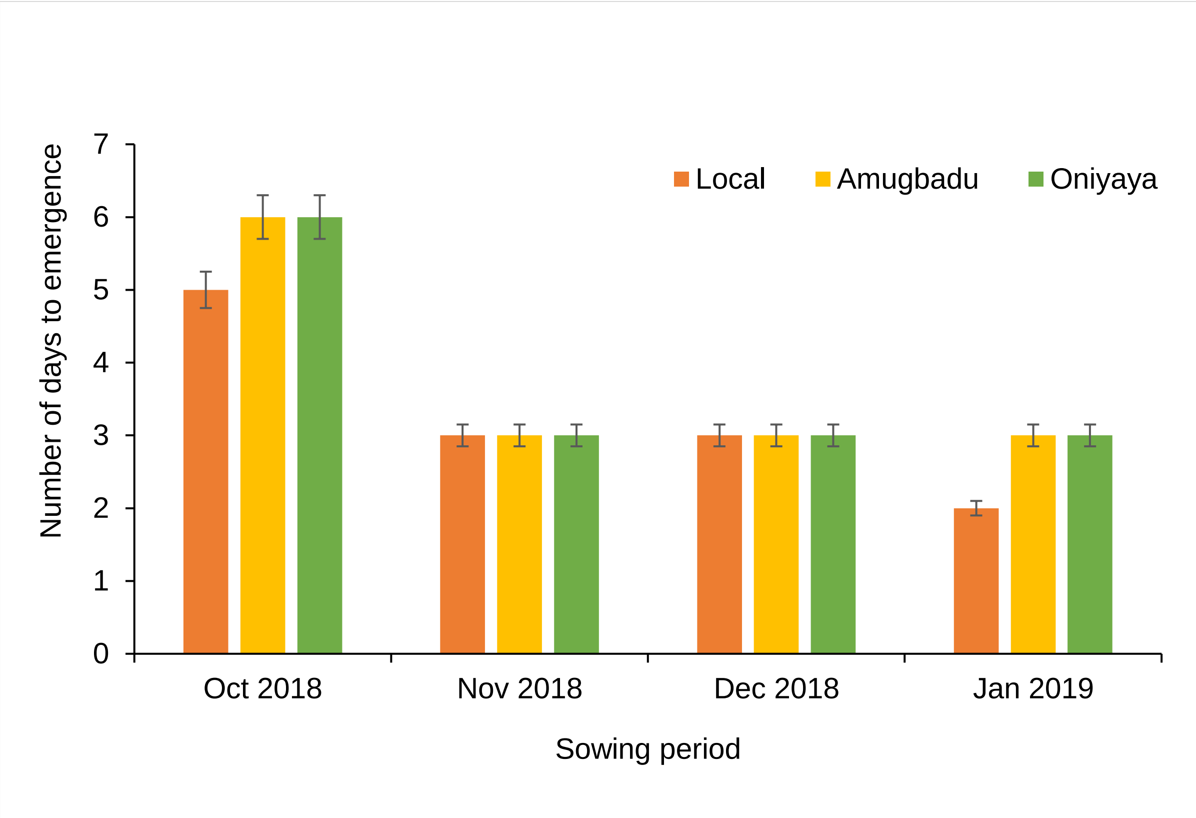


Figure 4.1: Planting period vs number of days to seedling emergence of three *C. olitorius* cultivars

Table 4.1: Minimum and maximum day temperatures (°C) from the day of seed sowing to 50% seedling emergence

Month/year	October 2018		November 2018		December 2018		January 2019	
Day	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)
1	16.5	27.8	17.1	34.2	20.1	32.1	18.4	32
2	12.5	20.9	18.3	30.2	18.6	30.6	19.2	33.5
3	14.1	28.7	17.4	26.1	21.2	33	19.5	32.8
4	13.2	25.3	17.7	31.1	18.9	28.5	16.8	24.3
5	10.6	20.8	19.7	34.1	18.9	25.6	13.4	26.5
6	8.6	20.1	16.6	26.9	17.3	29.5	11.8	30
7	8.1	21.1	16	23.1	16.5	28.9	14.6	31.2
Average	11.94	23.53	17.54	29.39	18.79	29.74	16.24	30.04

Source: South African Weather Service (2019), Polokwane station records

4.2 Mucilage content of three *C. olitorius* cultivars in response to planting period and growing condition

The combined effect of growing condition, planting period and cultivar had no significant influence ($P \leq 0.05$) on Jew's mallow mucilage content (Appendix 4.3). The mucilage content of Jew's mallow determines the sliminess of the crop. The interaction between cultivar and planting period; planting period and growing condition also did not significantly ($P \leq 0.05$) affect mucilage content (Appendix 4.3 and 4.4). However, combined effect of cultivar and growing condition significantly ($P < 0.05$) influenced mucilage content at 8 WAT (Figure 4.2). Thus, the variation observed was due to the cultivar's performance under the different growing conditions. The significantly highest quantity of mucilage at 8 WAT was obtained in Oniyaya cultivar under field condition whereas the least was recorded from Local cultivar under pot condition (Figure 4.2). The mucilage content of the three cultivars did not differ significantly ($P \leq 0.05$) at 6 WAT; however, significant ($P < 0.01$) differences were recorded at 8 WAT (Table 4.2).

The cultivar Oniyaya produced significantly highest average (184.58 mPa·s) mucilage content at 8 WAT while the lowest average value (124.58 mPa·s) was recorded in the Local cultivar (Table 4.2). This implies that Oniyaya cultivar produced the slimiest crops. The differences observed at 8 WAT may be attributed to the rate at which mucilage content decreased with age among cultivars. Generally, higher mucilage content was measured at 6 WAT compared to 8 WAT. The mucilage content of Jew's mallow appears to decline over time thus, the crop has higher mucilage content when young and tender. Moreover, it may also be as a result of biological differences among the cultivars. This suggests that it is necessary to harvest the crop early to maximise benefits derivable from high mucilage content or viscosity. The cultivar Oniyaya would then be a preferable option in South Africa for people in the northern part who according to (Van Rensburg *et al.,* 2007) prefer the sliminess of the crop.

Regarding the planting periods, significantly ($P < 0.01$) highest average quantity of mucilage content (255.28 mPa·s) of Jew's mallow was observed in December planting period, while the lowest mucilage content (104.72 mPa·s) was found in crops grown during the February planting period (Table 4.2). This might be due to the fact that December planted crops possibly had the most favourable conditions in terms of temperature across all growth stages for better development than the other planting periods. This temperature bears a resemblance to natural adaptation of native habitats of *C. olitorius*. Ngomuo *et al*. (2017) corroborated that the characteristic of this crop valued to make sauces that can be consumed with starchy foods is the production of mucilage from the leaves. The more mucilage content produced by the crop, the slimier the crop becomes. People in the southern regions of Africa would however be more prone to consuming the 'Local' cultivar which produces the least amount of mucilage. Van Wyk and Gericke (2000) stated that people in this region reduce the sliminess of *C. olitorius* by adding bicarbonate of soda or even cow urine to the cooking water.

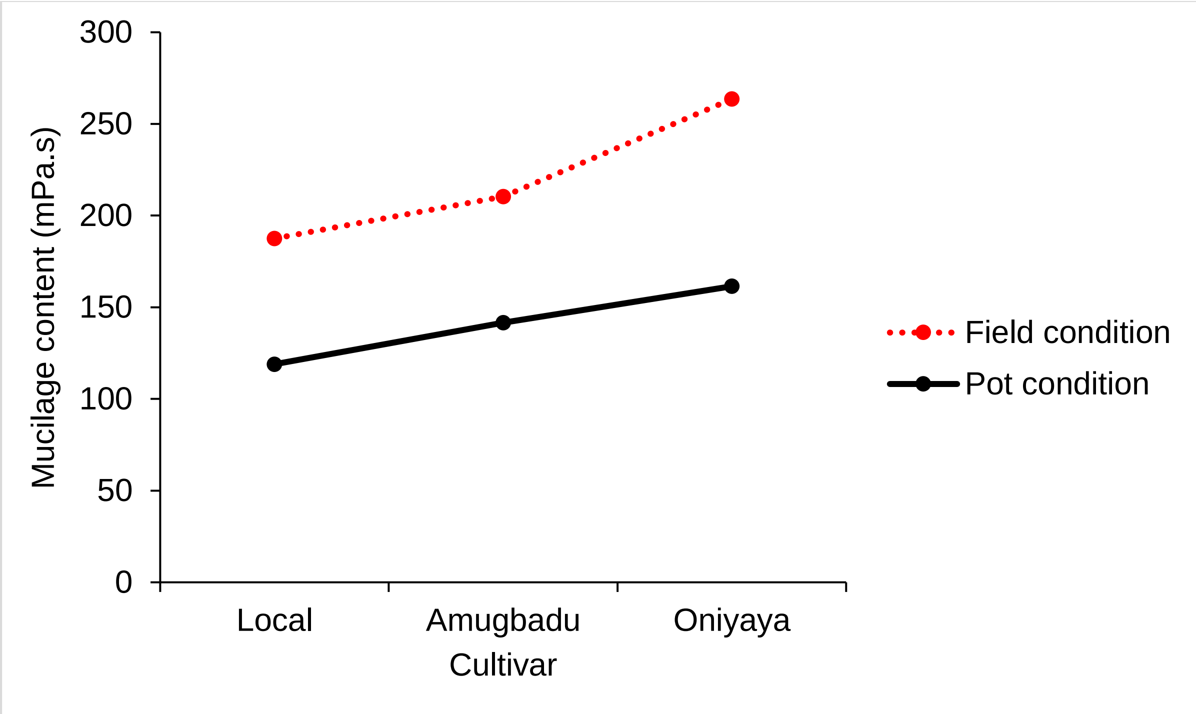


Figure 4.2: Effect of cultivar and growing condition on mucilage content (mPa·s) of *C. olitorius* at 8 WAT

Table 4.2: Effect of cultivar and planting period on mucilage content (mPa·s) of three *C. olitorius* cultivars

	Weeks after transplanting		
Treatment	6	8	Mean
Cultivar			
Local	181.88a	124.58b	153.23
Amugbadu	201.67a	150.42b	176.05
Oniyaya	240.42a	184.58a	212.50
Mean	207.99	153.19	180.59
Planting Period			
November	201.67ab	160.56a	181.12
December	255.28a	165.83a	210.56
January	235.56a	181.67a	208.62
February	139.44b	104.72b	122.08
Mean	207.99	153.20	180.59
P-values			
Planting Period* Cultivar	0.470^{ns}	0.205^{ns}	
Cultivar	0.181^{ns}	0.001**	
Planting Period	0.005**	0.001**	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

4.3 Effect of cultivar, planting period and growing condition on growth of three *C. olitorius* cultivars

4.3.1 Number of branches

The growth of *C. olitorius* in terms of number of branches was not affected by the combined effect of cultivar, planting period and growing condition. Hence an insignificant (P ≤ 0.05) interactive effect between the growing condition, planting period and cultivar on branch production (Appendix 4.17). Significant (P < 0.05) combined effect of cultivar and planting period was obtained on number of *C. olitorius* branches at 6 WAT (Figure 4.3). Similar trend was obtained at 8 and 10 WAT (Table 4.3). Furthermore, significant interaction between planting period and growing condition were also recorded (Figure 4.4). Thus, the differences observed were due more to the effect of the planting period and the growing condition. The significantly highest number of branches at 6 WAT was obtained in Oniyaya and Amugbadu cultivars during the November planting period. The test crop seedlings transplanted in February had the lowest average number of branches. Crops planted under pot and field conditions produced the highest average number of branches in November and December planting periods respectively (Figure 4.4). Cultivar and planting period had significant ($P < 0.05$) interactive effect on number of branches produced by *C. olitorius* at 6 and 8 WAT (Appendices 4.17 and 4.18). Thus, production of branches by *C. olitorius* varied with planting periods.

Comparing the cultivars at 6 and 8 WAT, Oniyaya produced significantly ($P < 0.01$) higher number of branches (13.67 and 16.67) than Local (12.33 and 15.00), respectively. The significant differences among the cultivars disappeared as the growing season progressed (10 to 16 WAT) (Table 4.3). This might be because *C. olitorius* is a leafy vegetable usually harvested at the vegetative stage. The 10 to 16 WAT must have coincided with the reproductive stage of the crop. Thus, the development of new branches ceased at the reproductive stage towards maturity as the crop expectedly channelled its energy towards flowering and capsule production.

Regarding the planting periods, significantly ($P < 0.001$) highest average number of branches per plant (14.89 and 14.10) were recorded in November and December periods respectively while the lowest (9.33) was observed in February planting period (Table 4.3). The greater number of branches observed in November and December relates with highest minimum and maximum temperatures which also occurred within the two months (Figure 3.8). This clearly indicates that during the two planting periods, the crop experienced high temperature throughout the growth stages and this may have stimulated branching. Temperatures dropped as the season changed and the growth overlapped to another season. This might have resulted in crops grown during the February period recording the lowest number of branches. February planting period means *C. olitorius* accumulated reduced heat units as the temperature dropped in autumn.

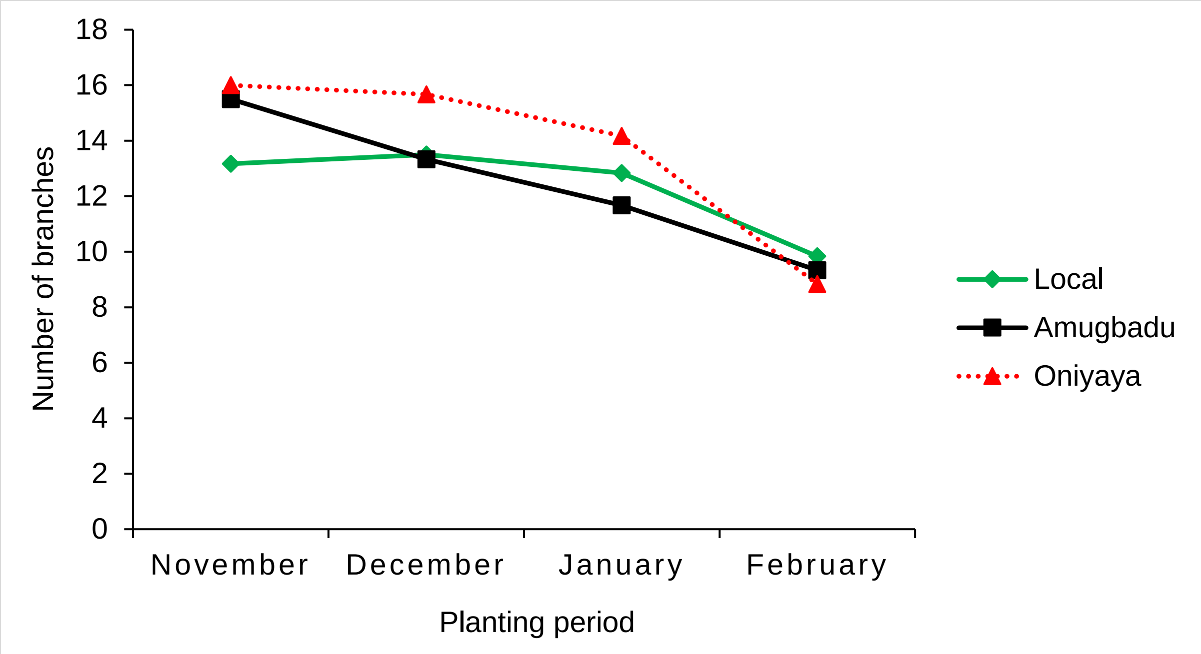


Figure 4.3: Effect of cultivar and planting period on number of branches per plant of *C. olitorius* at 6 WAT

Table 4.3: Effect of cultivar and planting period on number of branches per plant of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	12.33b	15.00b	17.71a	20.25a	21.63a	21.96a	18.15
Amugbadu	12.46b	15.75ab	18.54a	20.67a	21.92a	22.13a	18.58
Oniyaya	13.67a	16.67a	18.67a	20.63a	21.75a	22.04a	18.91
Mean	12.82	15.81	18.31	20.51	21.76	22.04	18.54
PP							
November	14.89a	17.28a	20.33a	22.94a	23.78ab	24.11ab	20.56
December	14.1ab	17.28a	20.33a	22.72a	25.11a	25.56a	20.85
January	12.89b	16.78a	18.44a	20.83b	22.00b	22.33b	18.88
February	9.33c	11.89b	14.11b	15.56c	16.17c	16.17c	13.87
Mean	12.82	15.81	18.31	20.51	21.76	22.04	18.54
P-values							
PP* Cv.	0.007**	0.001**	0.037*	0.347^{ns}	0.286^{ns}	0.399^{ns}	
Cultivar	0.004**	0.001**	0.085^{ns}	0.665^{ns}	0.836^{ns}	0.949^{ns}	
PP	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively.

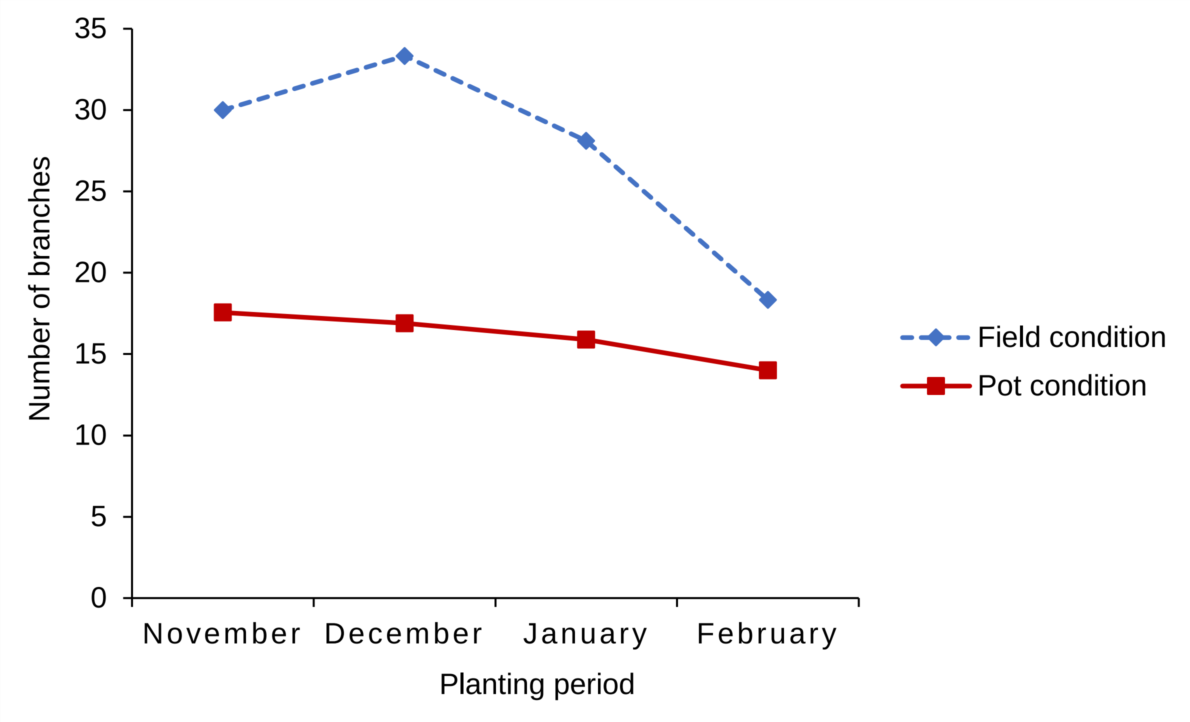


Figure 4.4: Effect of planting period and growing condition on number of branches per plant of *C. olitorius* at 14 WAT

4.3.2 Chlorophyll content

Cultivar, planting period and growing condition had a significant effect ($P < 0.001$) on chlorophyll content of *C. olitorius* across the different stages of growth (Appendices 4.5 to 4.10). Indicating that the chlorophyll content of *C. olitorius* varied with cultivar, planting period and also growing condition. Furthermore, there were significant ($P < 0.05$) differences in interactions between cultivar and planting period (Figure 4.5); cultivar and growing condition (Figure 4.6) and planting period and growing condition (Figure 4.7). The average highest chlorophyll content was obtained from Oniyaya cultivar during November period under pot condition (Figure 4.8). The significantly highest average chlorophyll content of Jew's mallow was obtained during the November planting period (Table 4.4), similar trend was observed for all cultivars under both growing conditions (Figure 4.8). Under the pot condition, Local cultivar had the least chlorophyll content than other combinations when planting occurred in December period. For Amugbadu and Oniyaya cultivars, the chlorophyll production was significantly reduced to minimum in January period under field condition, while for Local cultivar, such reduction occurred during the February planting period (Figure 4.8). Oniyaya followed a similar trend under pot conditions in December while the worst period in terms of chlorophyll production for Amugbadu was under pot condition in January planting period (Figure 4.8). Essentially, maximising chlorophyll production in *C. olitorius* can be achieved by planting Oniyaya during November period under pot condition whereas planting Local cultivar during December period under pot condition would have a similar but opposite effect.

The three *C. olitorius* cultivars also differ significantly ($P < 0.001$) in chlorophyll content (Table 4.4). Physiological dissimilarities among cultivars may have resulted in the differences in chlorophyll production pattern. Morphological divergence might have caused differences in interception of sunlight resulting in varied chlorophyll concentration among cultivars. Comparing the planting periods, significantly ($P < 0.001$) highest production of chlorophyll in November might be as a result of high average temperatures experienced during this planting period. Planting during November period exposed *C. olitorius* seedlings to high average optimum temperature which might result in higher chlorophyll concentration. Chlorophyll content is vital in photosynthetic plants like Jew's mallow to give them their green colour and channel sunlight into chemical energy. Jiang and Huang (2001) stated that the level of chlorophyll maintains the photosynthetic capability of plants. A study by El-Khoby (2004) reported that a later planting date reduced the amount of chlorophyll in crops. On gladiolus, Adil *et al*. (2013) discovered a strong positive association between temperature and chlorophyll concentration and emphasised that chlorophyll content is one of the most significant factors for determining a plant's health, because it is linked with physiological functions that produce food. An overall rise in chlorophyll and photosynthetic action at high temperatures was further stated.

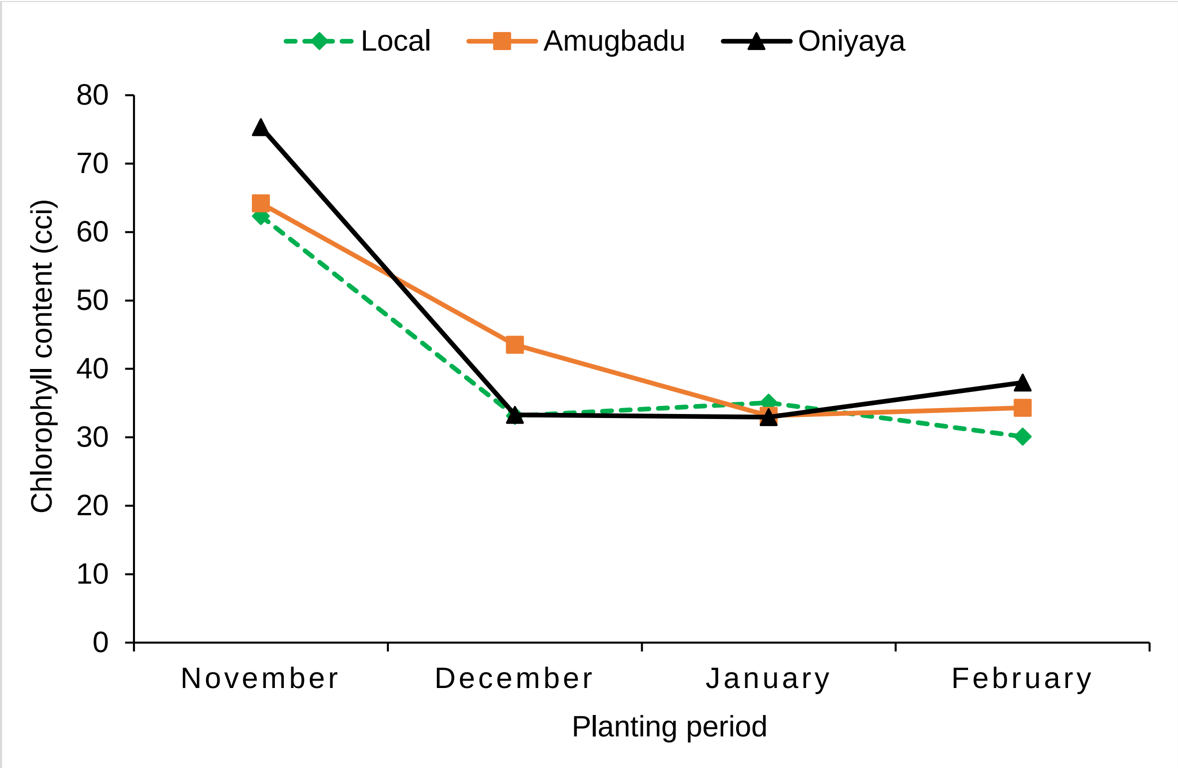


Figure 4.5: Effect of cultivar and planting period on chlorophyll content of *C. olitorius* at 10 WAT

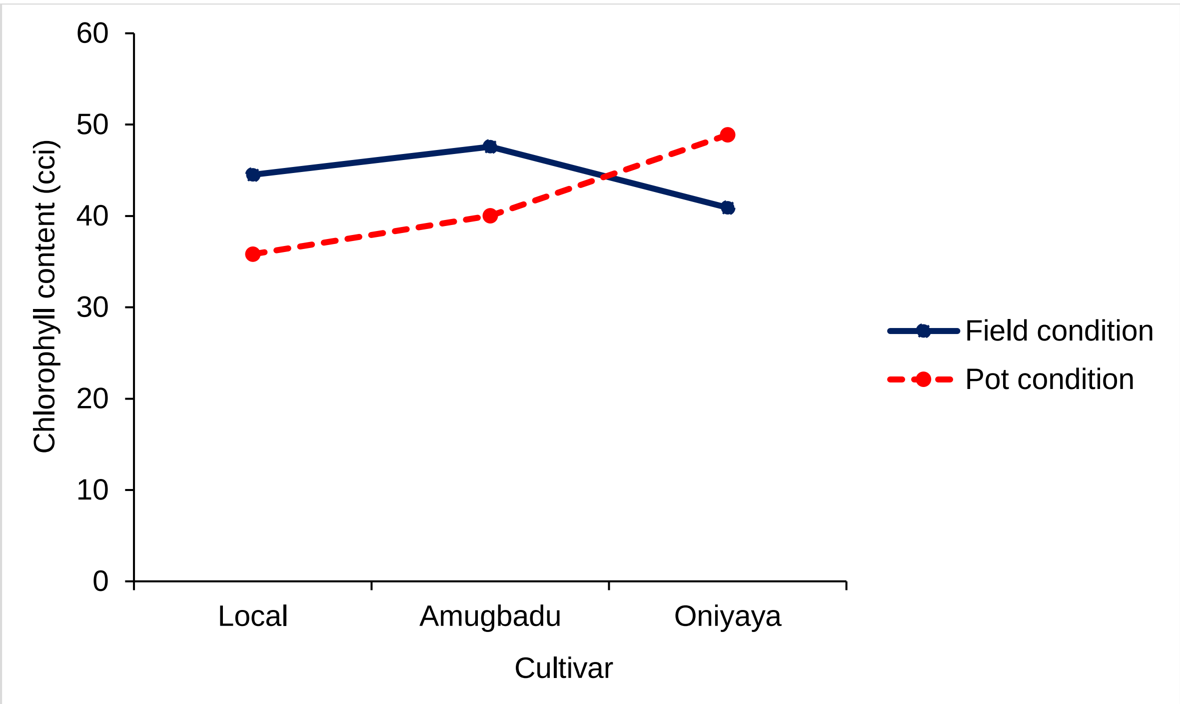


Figure 4.6: Effect of cultivar and growing condition on chlorophyll content of *C. olitorius* at 10 WAT

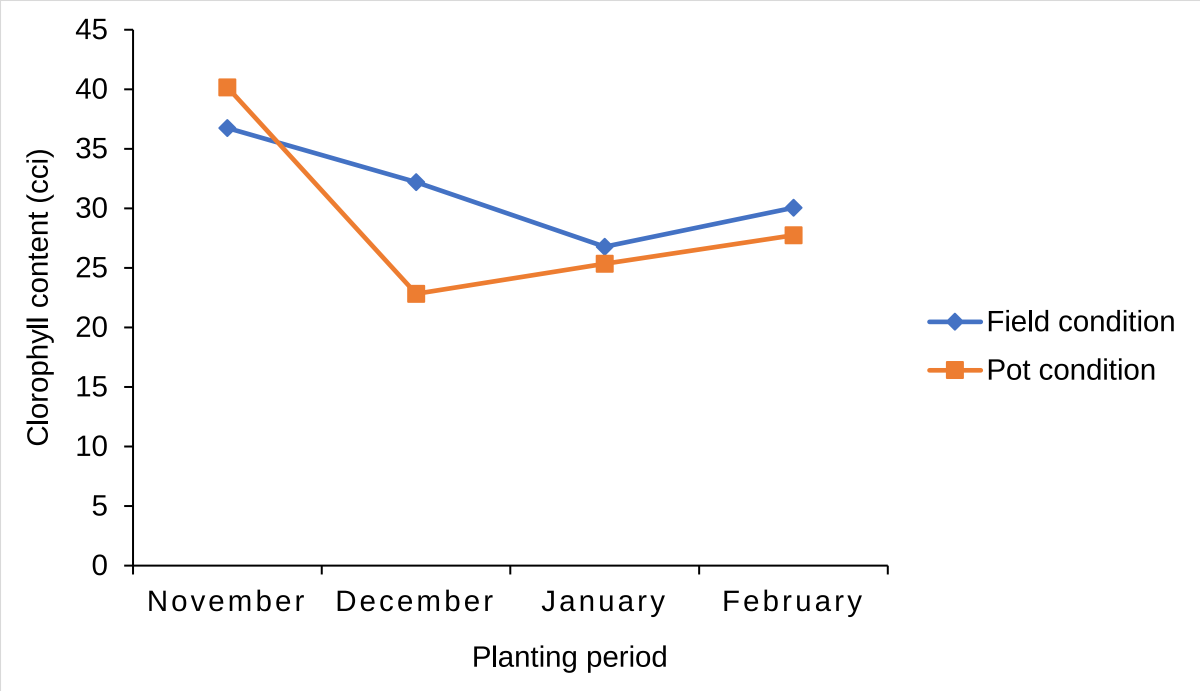


Figure 4.7: Effect of planting period and growing condition on chlorophyll content of *C. olitorius* at 14 WAT

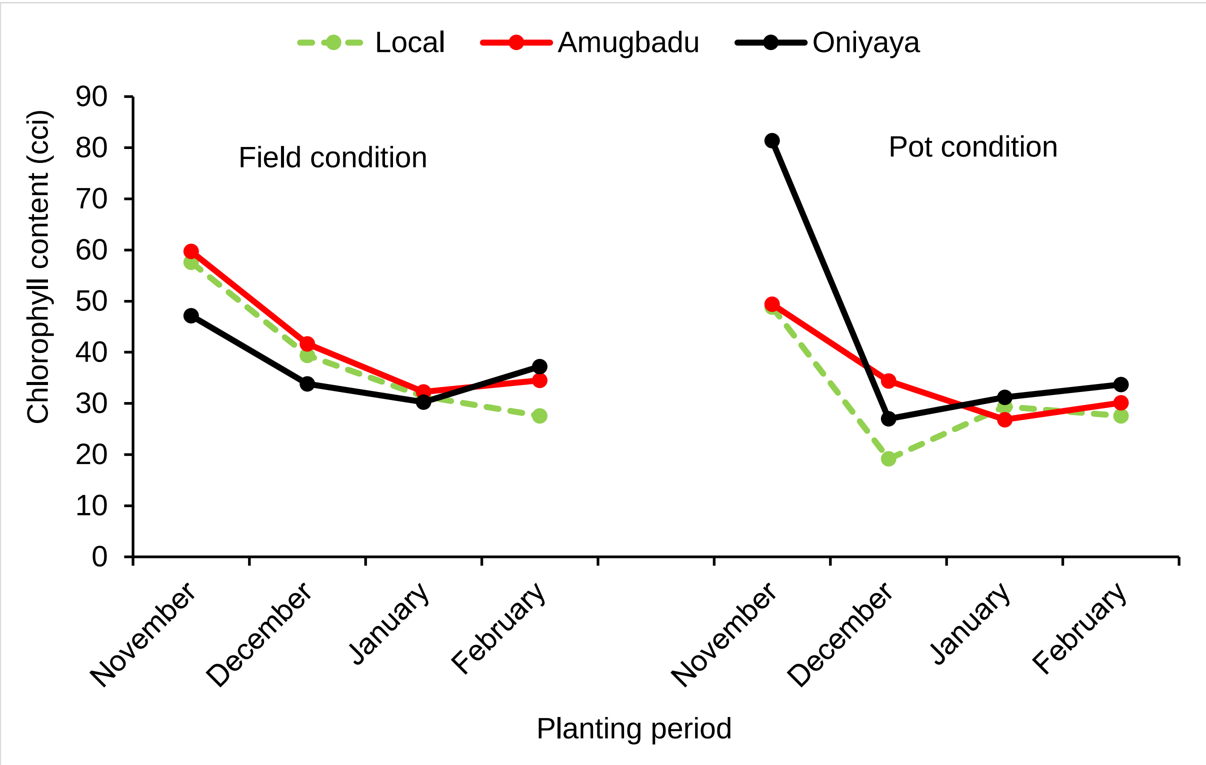


Figure 4.8: Effect of cultivar, planting period and growing condition on chlorophyll content of *C. olitorius* at 10 WAT

Table 4.4: Effect of cultivar and planting period on chlorophyll content of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	42.61b	43.39b	40.17b	33.11b	27.99b	23.38c	35.11
Amugbadu	47.34a	46.67a	43.80a	36.99a	30.98a	25.88b	38.61
Oniyaya	49.08a	49.16a	44.89a	37.14a	31.73a	29.21a	40.20
Mean	46.35	46.41	42.95	35.75	30.23	26.16	37.97
PP							
November	80.44a	78.02a	67.29a	48.67a	38.46a	31.21a	57.35
December	37.82b	38.00b	36.66b	32.17b	27.51bc	23.17bc	32.56
January	34.45b	34.38b	33.72b	29.88b	26.06c	22.79c	30.21
February	32.68b	35.23b	34.13b	32.26b	28.90b	27.47ab	31.78
Mean	46.35	46.41	42.95	35.75	30.23	26.16	37.97
P-values							
PP* Cv.	0.000***	0.000***	0.000***	0.000***	0.000***	0.002**	
Cultivar	0.000***	0.000***	0.000***	0.000***	0.000***	0.049*	
PP	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively

4.3.3 Number of leaves

Cultivar, planting period and growing condition had a significant (P < 0.05) influence on number of leaves of *C. olitorius* (Appendix 4.23 and 4.24). The superior average number of leaves at 8 WAT was recorded in Oniyaya and Local cultivars during December period and for Amugbadu during November period all under field condition (Figure 4.9). Moreover, crops transplanted in February had the lowest average number of leaves. Significant (P < 0.05) combined effects of cultivar and planting period (Figure 4.10); planting period and growing condition (Figure 4.11) were recorded in relation to leaf production in *C. olitorius*. Significant (P < 0.05) differences in leaf production among cultivars were obtained only at 8 WAT. Thus, minimal differences among the cultivars in relation to leaf production. In general, Oniyaya produced the highest average number of leaves compared to the other two cultivars (Table 4.5).

Significantly (P < 0.05) highest average number of leaves (151.61) was produced by Jew's mallow in the December period while significantly lowest mean value (44.61) was obtained during February planting period at 14 WAT (Table 4.5). Leaves are photosynthetic apparatus and thus directly affect crop growth and development, forms bulk of biomass and are the most harvested parts of leafy vegetables. Thus, for maximum production of *C. olitorius* leaves in the study area, January and February appear to be the worst periods for transplanting and therefore should be avoided. In addition, Amugbadu performed best in relation to leaf production during the November planting period, whereas December planting period appears to be superlative for Oniyaya and Local cultivars. This might be because January or February planting periods overlapped further into another season (autumn) wherein recorded weather conditions such as temperature and humidity were least favourable for *C. olitorius'* growth. The findings are in agreement with Ullah *et al*. (2013) who reported that for cabbage, planting time significantly affects number leaves.

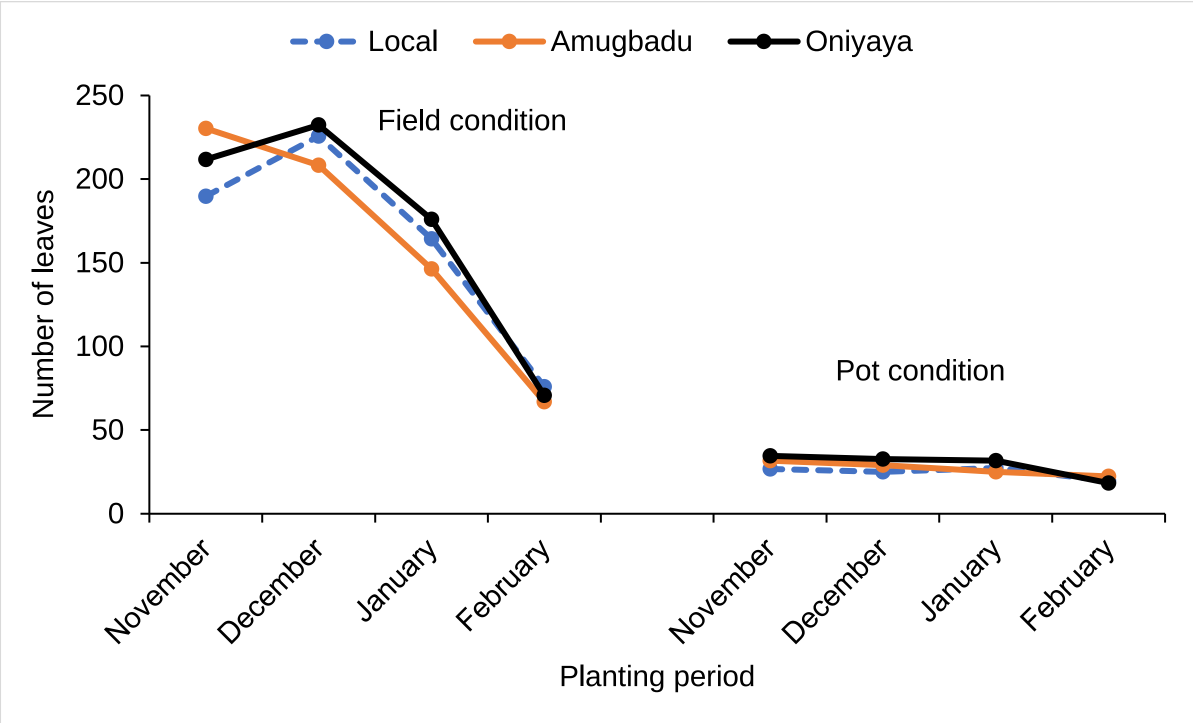


Figure 4.9: Effect of cultivar, planting period and growing condition on number of leaves per plant of *C. olitorius* at 8 WAT

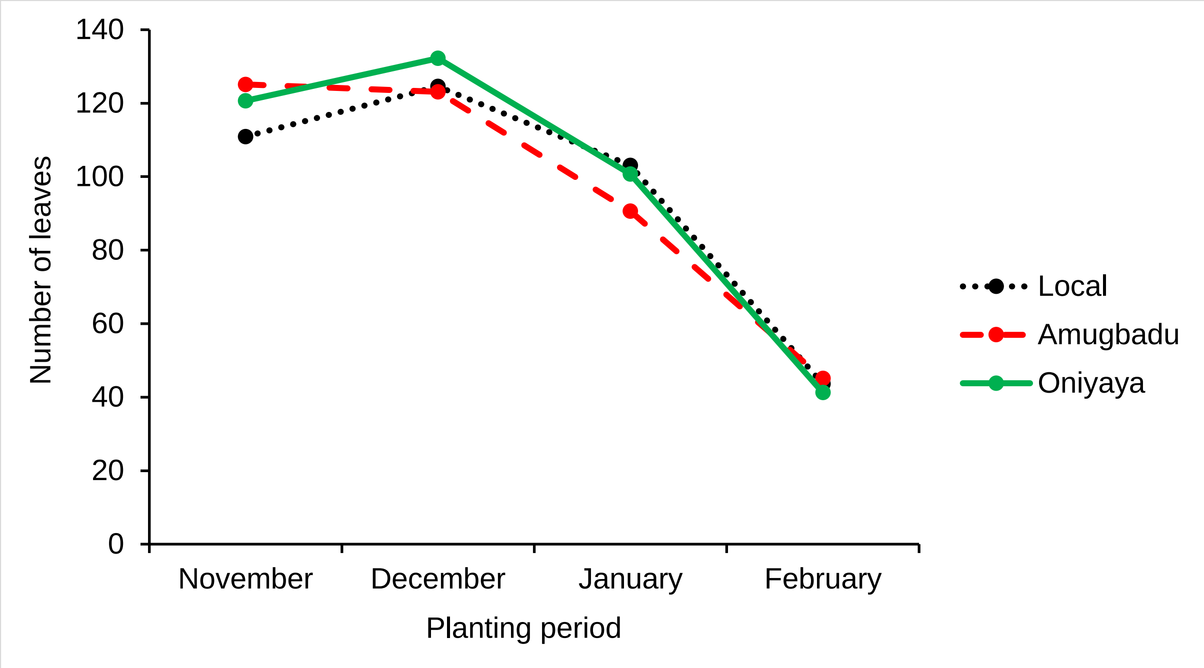


Figure 4.10: Effect of cultivar and planting period on number of leaves per plant of *C. olitorius* at 8 WAT

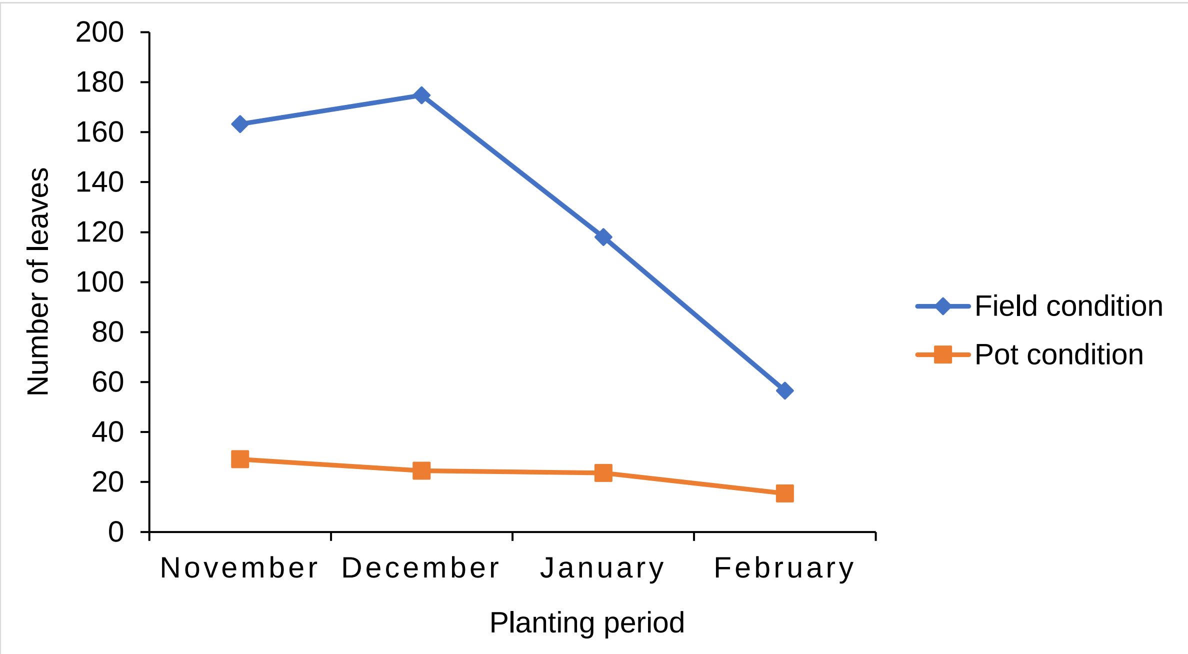


Figure 4.11: Effect of planting period and growing condition on number of leaves per plant of *C. olitorius* at 6 WAT

Table 4.5: Effect of cultivar and planting period on number of leaves per plant of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	73.75a	94.29b	113.00a	118.29a	116.71a	57.29a	95.56
Amugbadu	73.00a	95.00b	115.04a	118.17a	118.00a	56.71a	95.99
Oniyaya	80.25a	101.00a	115.92a	120.67a	117.75a	56.79a	98.73
Mean	75.67	96.76	114.65	119.04	117.49	56.93	96.76
PP							
November	96.17a	120.78a	146.94a	142.39a	141.1ab	66.00b	118.9
December	99.67a	125.50a	149.89a	150.50a	151.61a	82.67a	126.6
January	70.83b	95.11b	107.94b	123.94b	132.56b	58.56b	98.16
February	36.00c	45.67c	53.83c	59.33c	44.61c	20.50c	43.32
Mean	75.67	96.77	114.65	119.04	117.49	56.93	96.75
P-values							
PP* Cv.	0.004**	0.000***	0.036*	0.091^{ns}	0.027*	0.001**	
Cultivar	0.089^{ns}	0.016*	0.673^{ns}	0.728^{ns}	0.926^{ns}	0.960^{ns}	
PP	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively.

4.3.4 Plant height

Plant height of *C. olitorius* did not vary significantly (P ≤ 0.05) with the combined effect of the three treatment factors throughout growth duration (Appendix 4.29 to 34). However, the combined effect of cultivar and growing condition significantly (P < 0.05) affected *C. olitorius* plant height at 8 WAT (Figure 4.12). Furthermore, significant interaction between planting period and growing condition was observed at 12 WAT (Figure 4.13); thus, higher mean Jew’s mallow heights were obtained in November and December compared to January and February planting periods under both field and pot conditions (Figure 4.13). Local cultivar was significantly taller under the field condition; it might be because it was more adaptive to the environment than the other two cultivars. The significantly tallest plant was obtained during December period under field condition and in November under pot condition while the lowest mean value was obtained during the February planting period under both growing conditions (Figure 4.13). Significantly ($P < 0.01$) average highest height (79.64 cm) of *C. olitorius* was observed in the Local cultivar while the lowest average value (70.54 cm) was obtained in cultivar Amugbadu at 16 WAT (Table 4.6). The differences among cultivars in relation to plant height might be related to morphological variations, with a better light interception and photosynthetic competence, some cultivars grew taller and such structural characteristics can be important to growers.

Comparing planting periods, the significantly ($P < 0.001$) highest mean plant height (89.55 cm) was obtained during December planting and the shortest average value (46.34 cm) was obtained during February planting period at 16 WAT (Table 4.6). The planting period plays a vital role in growth of *C. olitorius*. Plant height is predictive of life span and time to maturity and is a major determinant of crops' ability to compete for light. The production of tallest plants in December planting relates to generally suitable average minimum and maximum temperatures which provided favourable growing conditions and allowed the *C. olitorius* crop to reach its maximum height. The findings agree with Barros *et al*. (2004), it was reported that changes in temperature and day duration during the growing season are linked to plant height reduction caused by delayed planting. Plant height in groundnut and amaranth were found to be reduced because of planting delays (Sajo and Mohammed, 2004; Yarnia, 2010). Tesfaye *et al.* (2018) reported significant difference in plant height and number of leaves as affected by planting time and argued that the taller crop stature offers added photosynthetic capability to the crop than shorter height with a superior quantity of leaves.

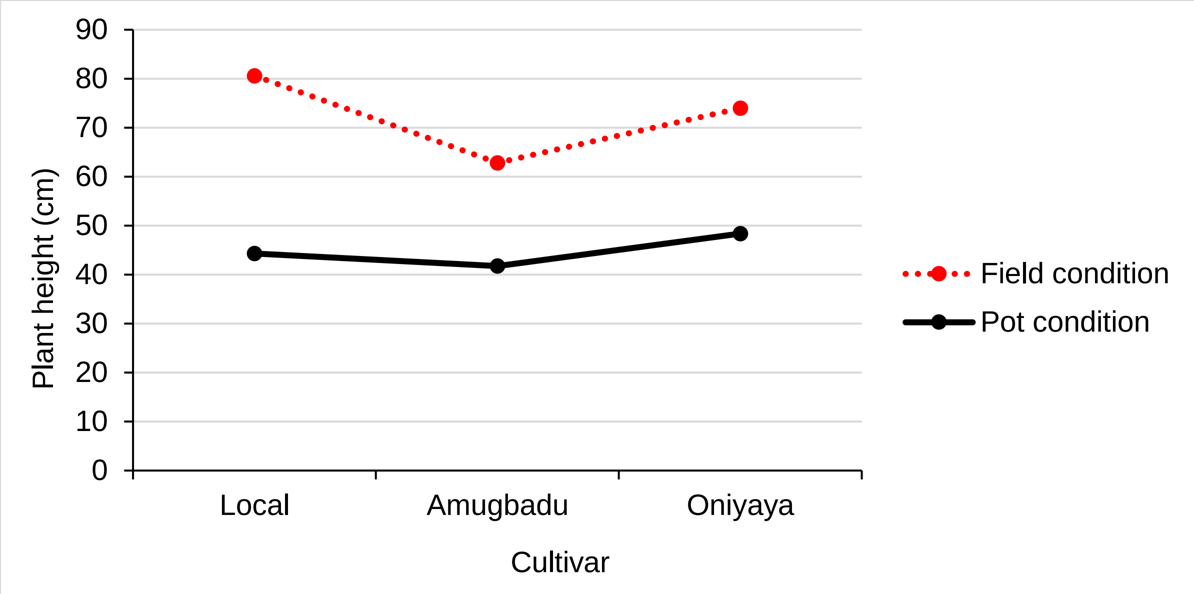


Figure 4.12: Effect of cultivar and growing condition and on plant height (cm) of *C. olitorius* at 8 WAT

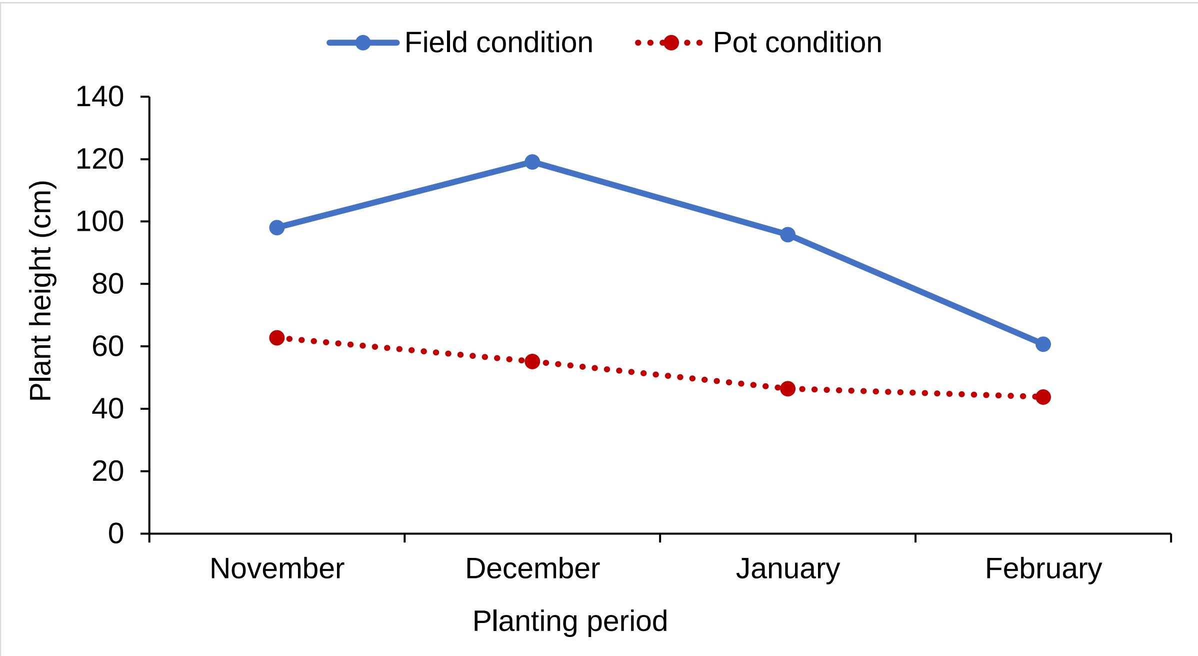


Figure 4.13: Effect of planting period and growing condition on plant height (cm) of *C. olitorius* at 12 WAT

Table 4.6: Effect of cultivar and planting period on plant height (cm) of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	48.01a	62.47a	71.00a	77.20a	79.22a	79.64a	69.59
Amugbadu	39.92b	52.29b	60.60b	66.24b	70.14b	70.54b	59.96
Oniyaya	47.27a	61.19a	69.74a	74.81a	78.29a	78.63a	68.32
Mean	45.07	58.65	67.11	72.75	75.88	76.27	65.96
PP							
November	43.40a	57.64b	69.47b	80.43a	88.66a	89.28a	71.48
December	51.81a	67.83ab	82.00a	87.17a	89.32a	89.55a	77.95
January	52.51a	71.32a	74.94ab	78.27a	79.52a	79.91a	72.75
February	32.55b	37.81c	42.06c	45.14b	46.03b	46.34b	41.66
Mean	45.07	58.65	67.12	72.75	75.88	76.27	65.96
P-values							
PP* Cv.	0.248^{ns}	0.225^{ns}	0.234^{ns}	0.124^{ns}	0.186^{ns}	0.181^{ns}	
Cultivar	0.001**	0.001**	0.001**	0.000***	0.002**	0.002**	
PP	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively.

4.3.5 Stem diameter

The stem diameter of *C. olitorius* highly varied significantly (P < 0.001) with the three treatment factors (Appendix 4.35). Jew's mallow grown under the field condition had significantly higher average stem diameter than those in the pot (Figure 4.14). The Amugbadu cultivar grown during November period under field condition resulted in the biggest average stem diameter of *C. olitorius*. Moreover, the smallest stem diameter under the field condition was produced by Oniyaya and Local cultivars in February period (Figure 4.14). Highly significant (P < 0.001) differences in combined effect of cultivar and planting period; cultivar and growing condition; planting period and growing conditions on stem diameter of *C. olitorius* were also recorded (Appendix 4.36). The significantly (P < 0.001) highest average values at 8 WAT were obtained from Amugbadu and Local cultivars during November and January periods, respectively. All cultivars had significantly smaller stem diameter during February planting period (Figure 4.15). At 6 WAT, Local cultivar obtained the average biggest and smallest stem diameter under field and pot conditions, respectively (Figure 4.16). Furthermore, significantly biggest stem diameter of *C. olitorius* was recorded during January period under field condition and during November period under pot condition (Figure 4.17). Highly significant cultivar differences were recorded on stem diameter of *C. olitorius*. Significantly higher mean Jew's mallow stem diameter was obtained in Local cultivar compared to Amugbadu and Oniyaya cultivars. In comparison of planting periods, significantly ($P < 0.001$) smallest stem diameter was recorded in February planting period (Table 4.7), wherein the least favourable weather conditions such as sunshine hours and temperature occurred compared to other planting period, hence smaller stem diameter.

All cultivars generally performed significantly better under field condition, which means the condition represented the natural growing environment for Jew's mallow while the pot condition may have been restrictive of the general vegetative growth of the crop resulting in smaller stem diameter. This suggest that the unrestrictive nature of the field condition in terms of unlimited nutrient supply and soil depth for root growth combined with the most favourable temperatures in November resulted in generally better stem growth. Stem diameter is an important measure to assess how plants grow and adapt to different environmental conditions. The reduced stem diameter in February planting period agrees with the findings of Kanase *et al*. (2018) in broccoli. It was stated that lower day and night average temperatures that prevail during vegetative growth could have resulted in small stem girth.

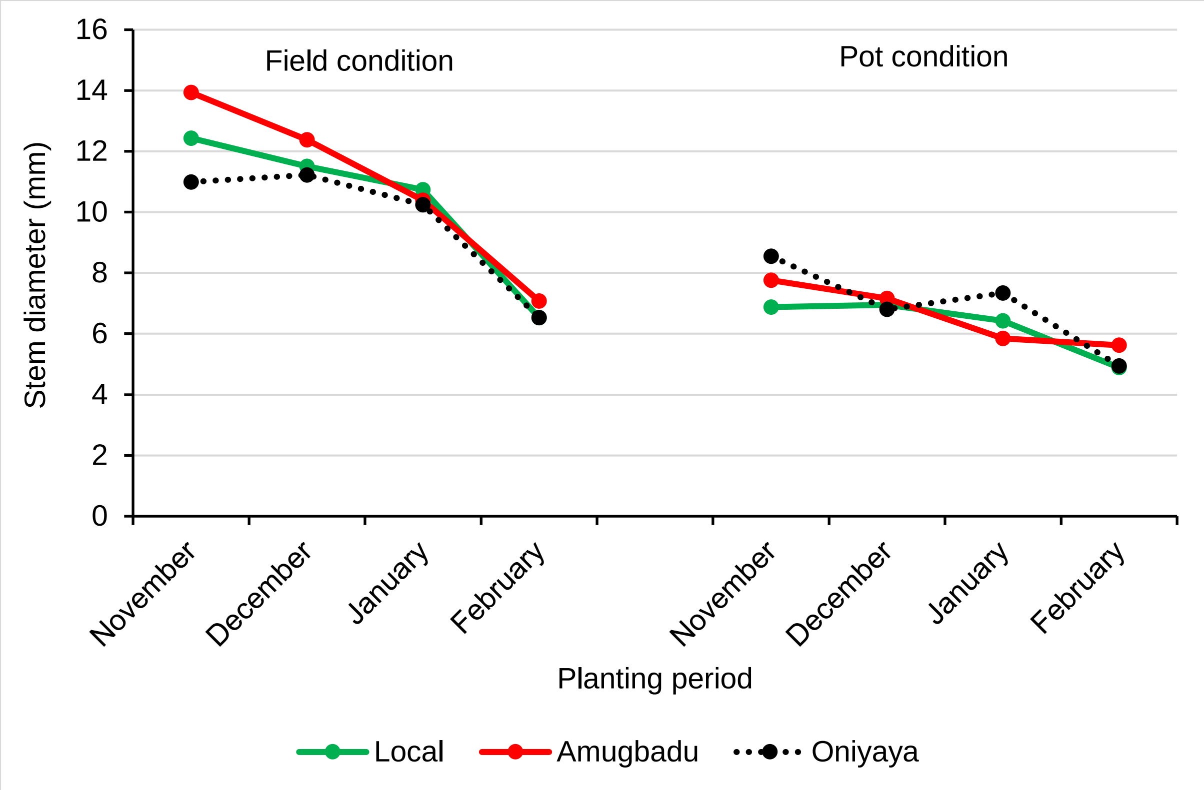


Figure 4.14: Effect of cultivar, planting period and growing condition on stem diameter (mm) of *C. olitorius* at 14 WAT

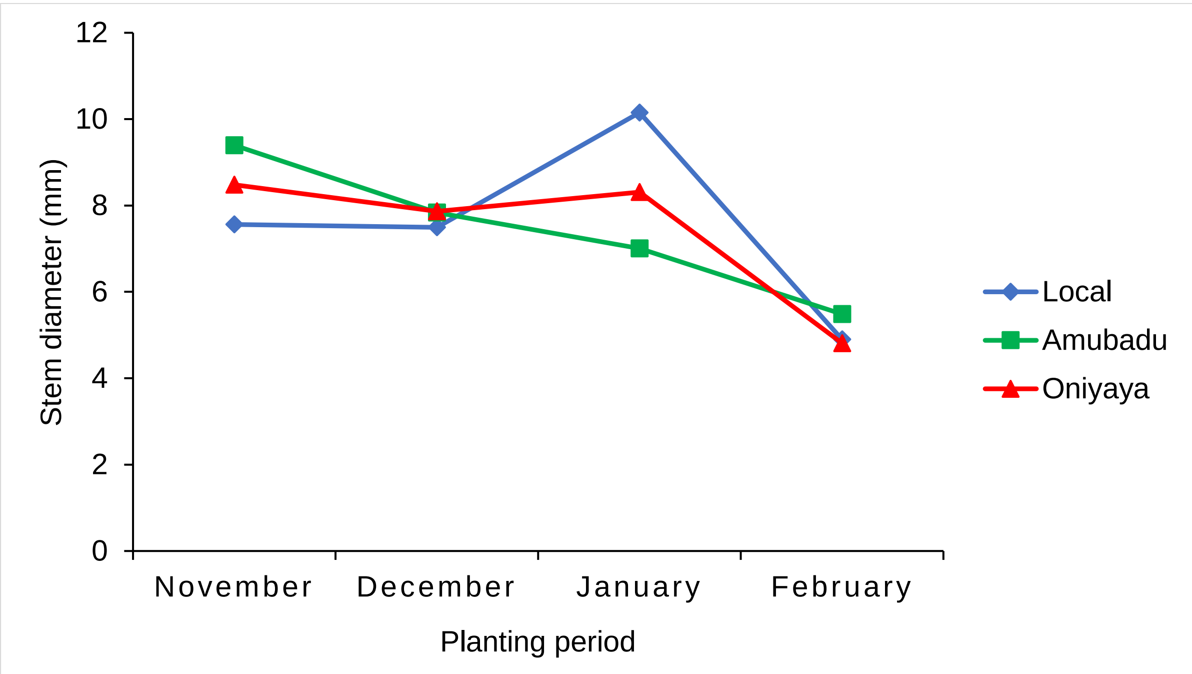


Figure 4.15: Effect of cultivar and planting period on stem diameter (mm) of *C. olitorius* at 8 WAT

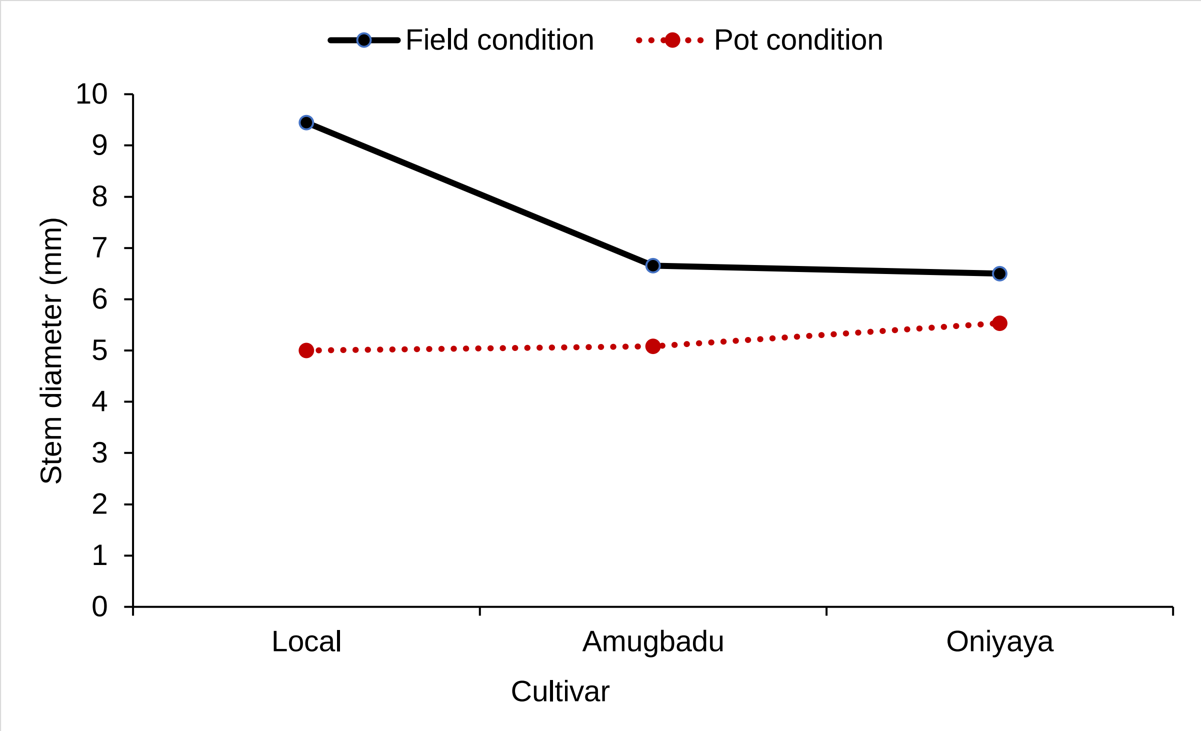


Figure 4.16: Effect of cultivar and growing conditions on stem diameter (mm) of *C. olitorius* at 6 WAT

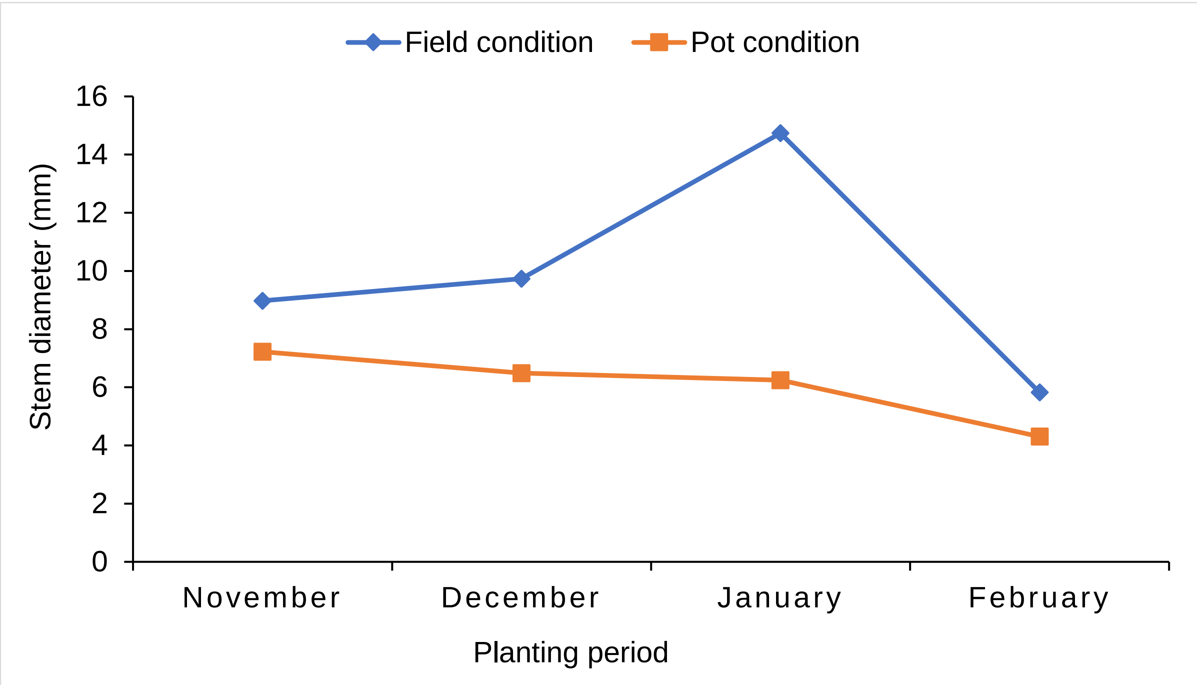


Figure 4.17: Effect of planting period and growing condition on stem diameter (mm) of *C. olitorius* at 8 WAT

Table 4.7: Effect of cultivar and planting period on stem diameter (mm) of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	7.22a	9.03a	10.71a	12.34a	13.37a	13.60a	11.04
Amugbadu	5.87b	7.434b	8.75b	9.76b	10.36b	10.48b	8.77
Oniyaya	6.02b	7.37b	8.23b	9.10b	9.56c	9.71c	8.33
Mean	6.37	7.94	9.23	10.40	11.10	11.26	9.38
PP							
November	7.26a	8.48b	9.96b	11.27b	11.74b	11.84b	10.09
December	6.33b	7.73b	9.08c	10.18c	11.22b	11.48b	9.34
January	7.906a	10.49a	11.86a	13.47a	14.49a	14.80a	12.17
February	4.00c	5.06c	6.01d	6.67d	6.93c	6.93c	5.93
Mean	6.37	7.94	9.23	10.40	11.10	11.26	9.38
P-values							
PP* Cv.	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	
Cultivar	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	
PP	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively.

4.3.6 Leaf area

The three treatment factors had no significant combined effect (P ≤ 0.05) on Jew's mallow leaf area (Appendix 4.11). Whereas the Jew's mallow leaf area varied significantly (P < 0.05) with combined effect of cultivar and planting period (Table 4.8) with the average highest value obtained in Amugbadu cultivar in November planting period (Figure 4.18). Amugbadu grown under the field condition had significantly higher mean value compared to others (Figure 4.19). Significant variation was also obtained in relation to combined effect of planting period and growing condition in relation to leaf area (Figure 4.20). The trend varied based on the planting period, with the highest average value recorded in November period.

Among the cultivars, significant ($P < 0.05$) widest average leaf area was obtained in cultivar Amugbadu particularly at 6, 12 and 14 WAT, while the differences in Oniyaya and Local average leaf area were not significantly different from each other (Table 4.8). The difference among cultivars may be because of morphological differences and also, around 10 to 16 WAT the crops had started to shed most of their big leaves as they were already out of vegetative stage and further into reproductive stage, this might have caused the variation. This transition might have resulted in most assimilates in the crop channelled towards reproductive parts like flowers and pods at the expense of leaves' growth.

The significantly (35.20 cm^2) widest leaf area at 10 WAT in relation to planting period was obtained in November planting period, while the least significant values (24.31 and 21.98 cm^2) were obtained in February and January periods respectively (Table 4.8). The differences observed among planting periods may be attributed to the fact that when planting occurs in November, the crop had longer time for vegetative growth resulting in leaves expanding to the fullest while later than this month resulted in shortened vegetative period of the crop vis-a-vis leave expansion. Leaf area is a reliable plant growth parameter because it is an important indicator of radiation interception capacity and solar energy conversion into chemical energy (photo-assimilates). The leaf surface area has a direct link with all photosynthetic light harvested which affects the overall plant growth and crop yield. Yarnia (2010) expressed that early planting date boosted amaranth leaf area and water absorption during the key period between flower bud appearances and flowering.

Table 4.8: Effect of cultivar and planting period on leaf area (cm^2) of *C. olitorius*

	Weeks after transplanting						
Treatment	6	8	10	12	14	16	Mean
Cultivar							
Local	23.94b	25.09b	26.00a	22.43b	15.87b	11.50a	20.81
Amugbadu	28.93a	30.08a	29.37a	26.80a	18.62a	13.50a	24.55
Oniyaya	24.98b	27.98ab	27.31a	20.90b	15.22b	13.77a	21.69
Mean	25.95	27.72	27.56	23.38	16.57	12.93	22.35
PP							
November	34.21a	34.63a	35.20a	27.92a	18.72a	12.6ab	27.22
December	24.09b	27.76b	28.74b	25.76ab	16.66a	12.0ab	22.50
January	23.15b	23.21c	21.98c	17.69b	13.30b	10.46b	18.30
February	22.35b	25.27bc	24.31bc	22.14ab	17.61a	16.57a	21.38
Mean	25.95	27.72	27.56	23.38	16.57	12.93	22.35
P-values							
PP* Cv.	0.009**	0.260ns	0.012*	0.030*	0.003**	0.017*	
Cultivar	0.000***	0.049*	0.097ns	0.000***	0.001*	0.108ns	
PP	0.000***	0.000***	0.000***	0.015*	0.000***	0.049*	

PP and Cv imply planting period and cultivar, respectively

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001, respectively.

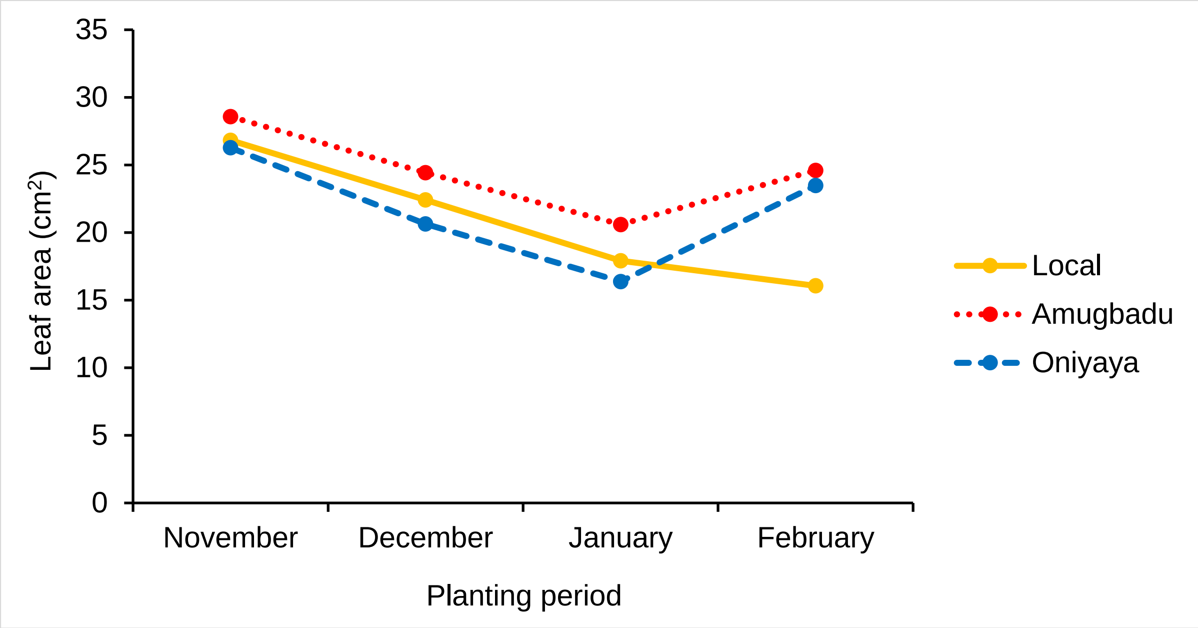


Figure 4.18: Effect of cultivar and planting period on leaf area (cm^2) of *C. olitorius* at 14 WAT

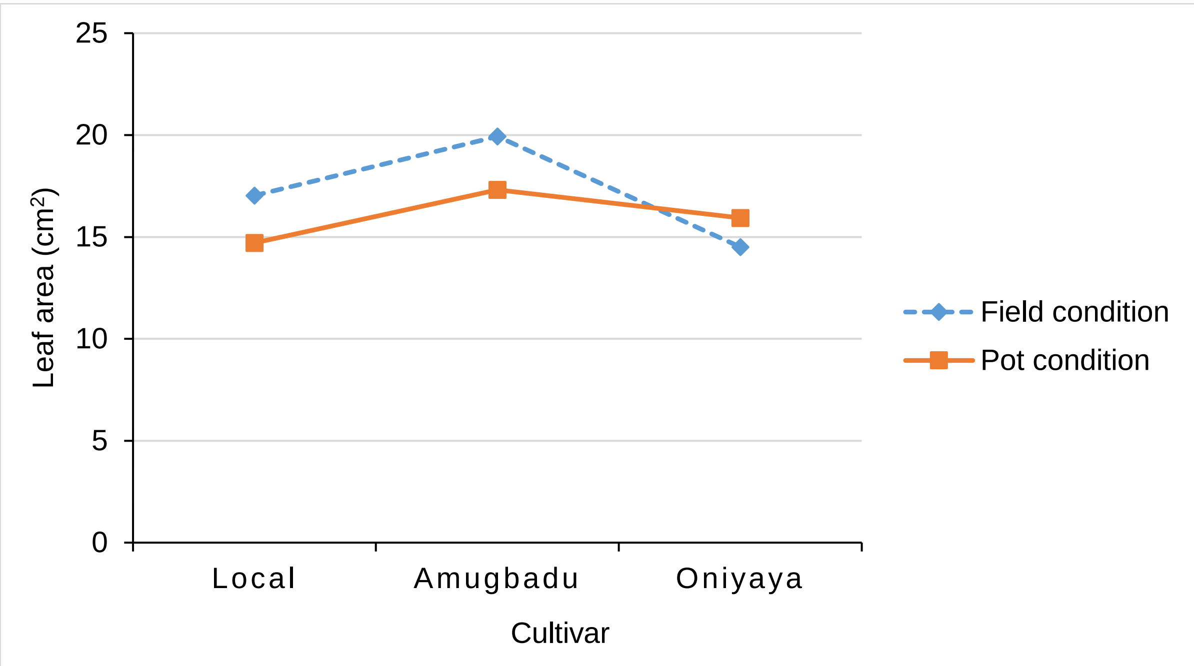


Figure 4.19: Effect of cultivar and growing condition on leaf area (cm^2) of *C. olitorius* at 14 WAT

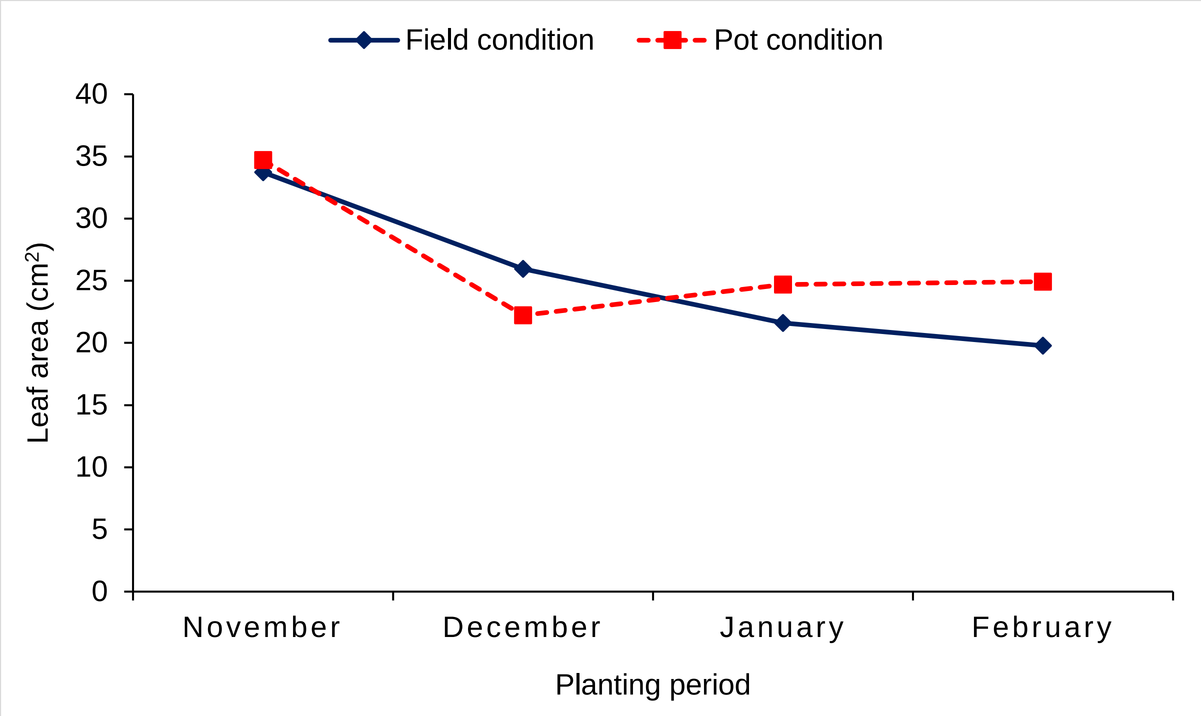


Figure 4.20: Effect of planting period and growing condition on leaf area (cm^2) of *C. olitorius* at 6 WAT

4.4 Effect of cultivar, planting period and growing condition on biomass production of three *C. olitorius* cultivars

4.4.1 Fresh shoot biomass

Cultivar, planting period and growing condition had no significant ($P \leq 0.05$) influence on *C. olitorius* fresh shoot mass (Appendix 4.44). Similar insignificant combined effect was obtained for cultivar and growing condition (Appendix 4.44); cultivar and planting period on *C. olitorius* fresh shoot mass (Table 4.9). On the other hand, planting period and growing condition had highly significant ($P < 0.001$) effect on fresh shoot mass of *C. olitorius* (Appendix 4.44). The greatest average fresh shoot mass was obtained during December period under field condition while the least value was recorded in February period under pot growing condition (Figure 4.21). No significant ($P \leq 0.05$) differences were found in fresh shoot mass among cultivars (Appendix 4.44). On the contrary, planting period showed highly significant ($P < 0.001$) differences in relation to *C. olitorius* fresh shoot mass (Table 4.9). The significantly highest average fresh shoot mass was obtained during December period (101.24 g at 6 WAT and 132.00 g at 18 WAT) and the lowest average values in February (22.15 g at 6 WAT and 30.84 g at 18 WAT) (Table 4.9). These differences may be ascribed to response to temperature and humidity. The optimum temperature and humidity recorded in December (Figure 3.8 and 3.9) might have influenced vegetative growth and the accumulation of fresh biomass. For example, in Chinese cabbage fresh leaf yield, the planting date was reported to be the most important yield element (Juma *et al*., 2005). According to Ullah *et al*. (2013), different planting time affected weight of plants. In addition, it was stated that optimum planting time ensures proper growth of plant and consequently the highest plant weight. Convergent with the findings was Rashwan (2011) who stipulated that *C. olitorius* grows well under high humidity and there appears to be proportional relation between humidity and fresh shoot biomass.

Table 4.9: Effect of cultivar and planting period on fresh shoot mass (g) of *C. olitorius*

	Weeks after transplanting		
Treatment	6	18	Mean
Cultivar			
Local	52.10a	91.44a	71.77
Amugbadu	54.64a	88.61a	71.62
Oniyaya	49.58a	88.53a	69.05
Mean	52.10	89.52	70.81
Planting Period			
November	19.48c	108.56ab	64.02
December	101.24a	132.00a	116.62
January	65.55b	86.69b	76.12
February	22.15c	30.84c	26.50
Mean	52.11	89.52	70.81
P-values			
Planting Period* Cultivar	0.995^{ns}	0.688^{ns}	
Cultivar	0.751^{ns}	0.956^{ns}	
Planting Period	0.000^{***}	0.000^{***}	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

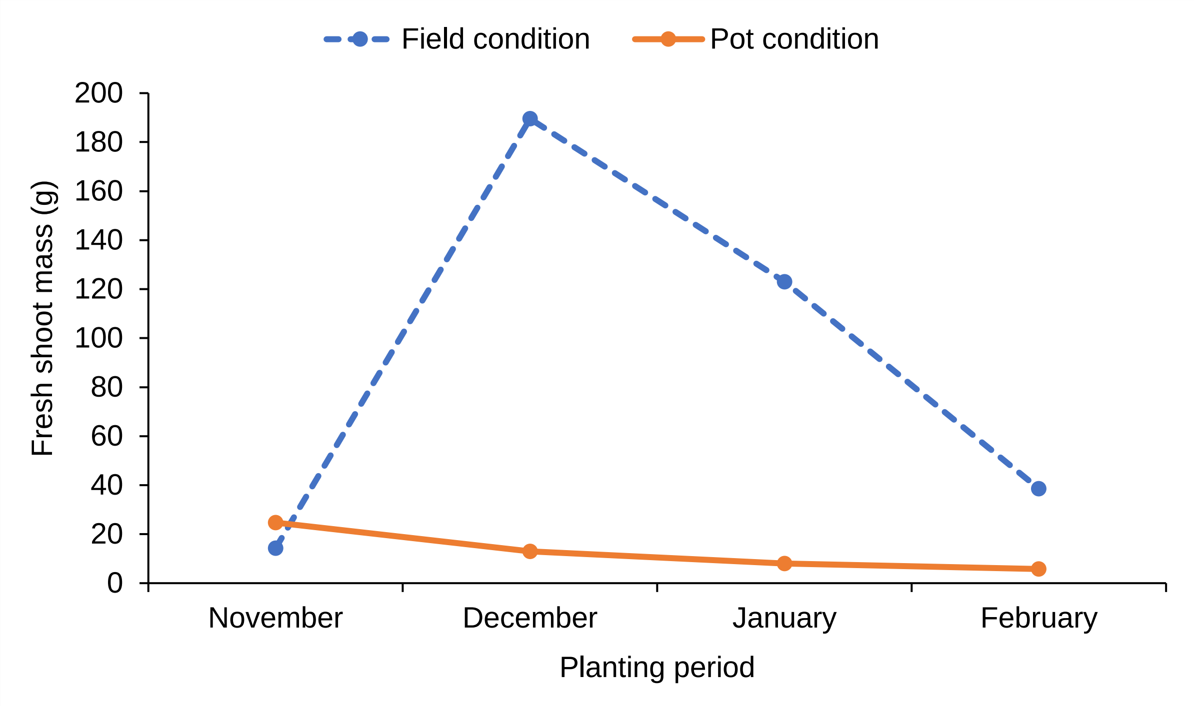


Figure 4.21: Effect of planting period and growing condition on fresh shoot mass (g) of *C. olitorius* at 6 WAT

4.4.2 Dry shoot biomass

The combined effect of the three treatment factors had no significant (P ≤ 0.05) influence on dry shoot mass of *C. olitorius*. Similarly, insignificant interactions (P ≤ 0.05) in relation to *C. olitorius* dry shoot mass were obtained between cultivar and planting period (Table 4.10); cultivar and growing condition (Appendix 4.42). Despite these insignificances, a combined effect of planting period and growing condition significantly (P < 0.001) influenced *C. olitorius* dry shoot mass (Appendix 4.42). The greatest average dry shoot mass at 18 WAT was obtained during December planting period under field condition. Irrespective of growing condition, crops transplanted during February period yielded the least average amount of dry shoot mass (Figure 4.22). The cultivars were not significantly (P ≤ 0.05) different in terms of dry shoot mass (Table 4.10), whereas the planting period had a highly significant (P < 0.001) effect on *C. olitorius* dry shoot mass (Table 4.10). The significantly highest average values were obtained in December (21.77 g at 6 WAT and 125.97 g at 18 WAT) while the least values were obtained in February (5.50 g at 6 WAT and 27.98 g at 18 WAT) (Table 4.9). It is evidently clear according to Figure 3.8 that the ideal growing condition in terms of optimum temperatures, minimum 18 °C and maximum 30 °C (Rashwan,

2011) were best obtained in December. This ideal temperature might have contributed considerably to dry matter accumulation in *C. olitorius.* Thus, it is likely that many smallholder farmers in Limpopo Province can benefit from these conditions since majority plant their crops in the late November to early December when rains tend to be reliable*.* The findings in this study are in line with the findings by Adil *et al*. (2013) it was reported that dry matter production increases at high temperature and that it may be attributed to greater accumulation of photosynthates by vegetative parts of the crop. Earlier findings by Zhao *et al*. (2006) detailed that plant growth contributes wholly to the increase of fresh and dry matter.

Table 4.10: Effect of cultivar and planting period on dry shoot mass (g) of *C. olitorius*

	Weeks after transplanting		
Treatment	6	18	Mean
Cultivar			
Local	12.94a	80.21a	46.57
Amugbadu	14.20a	92.49a	53.35
Oniyaya	12.10a	83.17a	47.64
Mean	13.08	85.29	49.18
Planting Period			
November	11.16b	103.46ab	57.31
December	21.77a	125.97a	73.87
January	13.90b	83.75b	48.82
February	5.50c	27.98c	16.74
Mean	13.08	85.29	49.19
P-values			
Planting Period* Cultivar	0.934^{ns}	0.463^{ns}	
Cultivar	0.321^{ns}	0.492^{ns}	
Planting Period	0.000***	0.000***	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

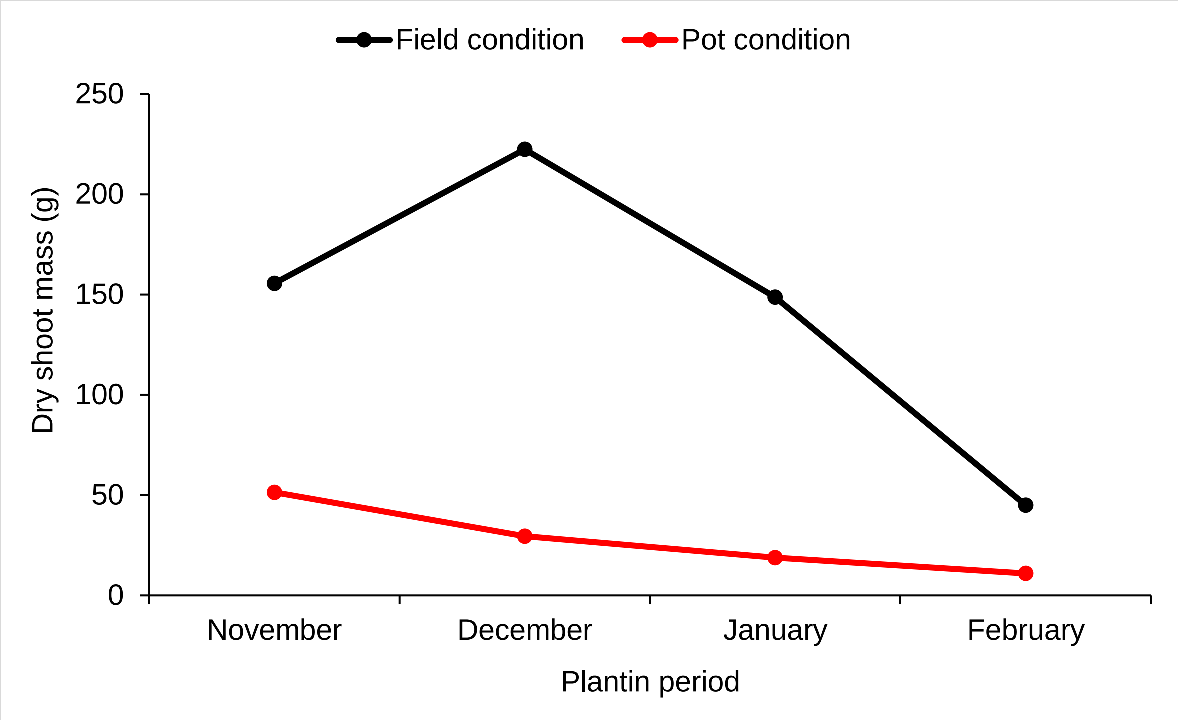


Figure 4.22: Effect of planting period and growing condition on dry shoot mass (g) of *C. olitorius* at 18 WAT

4.4.3 Fresh root biomass

Cultivar, planting period and growing condition had a significant ($P < 0.05$) influence on fresh root mass of *C. olitorius* (Appendix 4.45). Significantly, highest fresh root mass was obtained from Local cultivar during November period under field conditions, whereas the lowest average value was recorded in all cultivars during February period under pot condition (Figure 4.23). Furthermore, significant ($P < 0.05$) combined effect of cultivar and planting period; cultivar and growing condition; planting period and growing condition on fresh root mass of *C. olitorius* were observed (Appendix 4.43). The significantly ($P < 0.05$) highest fresh root mass at 6 WAT was obtained from Amugbadu and Local cultivars during November planting period (Figure 4.24). Oniyaya cultivar produced the greatest and least fresh root masses under pot and field conditions, respectively (Figure 4.25). Oniyaya root mass seemed to be more affected by growing condition than others. At 6 WAT, *C. olitorius* grown during the November and February planting periods had significantly greatest and least average fresh root mass under both growing conditions (Figure 4.26). The difference in physiological root branching and root growth of the cultivars might have resulted in the differences in root mass among them. High temperatures in November period and early planting meant extended exposure to favourable growing conditions allowing for further root growth. Proper sowing and transplanting time play an important role in achieving good vegetative yield (Yoldas and Esiyok, 2004). Sometimes farmers are using improved technologies for higher yield and quality crop. However, in many cases they do not follow the appropriate date of sowing for Jew's mallow cultivation. As a result, they do not get satisfactory yield. According to Hossain *et al*. (2015), about 12% of yield increment is obtained when timely planting and weeding are completed.

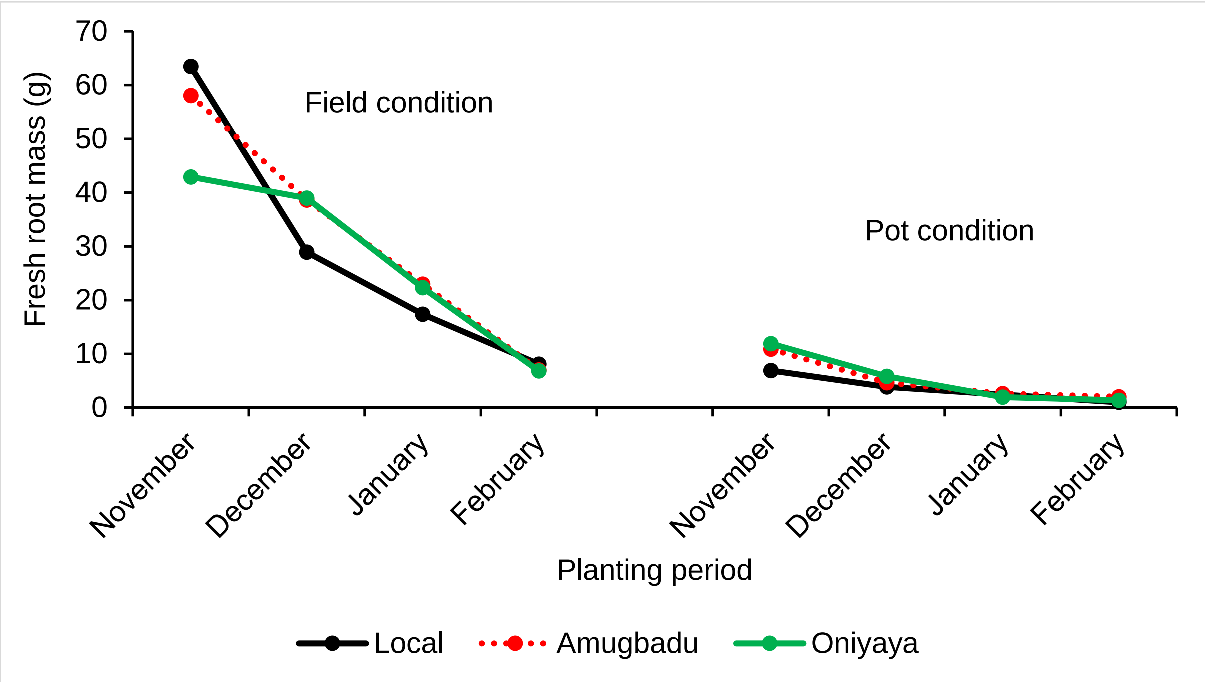


Figure 4.23: Effect of cultivar, planting period and growing conditions on fresh root mass (g) of *C. olitorius* at 6 WAT

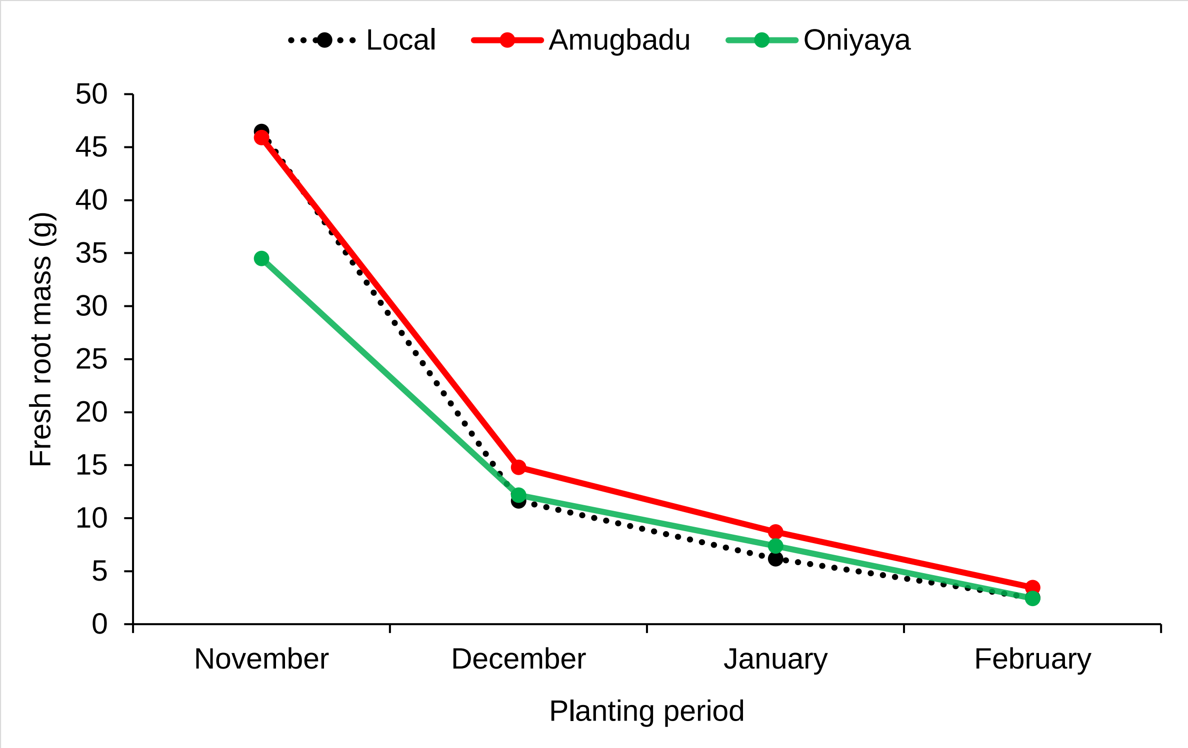


Figure 4.24: Effect of cultivar and planting period on fresh root mass (g) of *C. olitorius* at 6 WAT

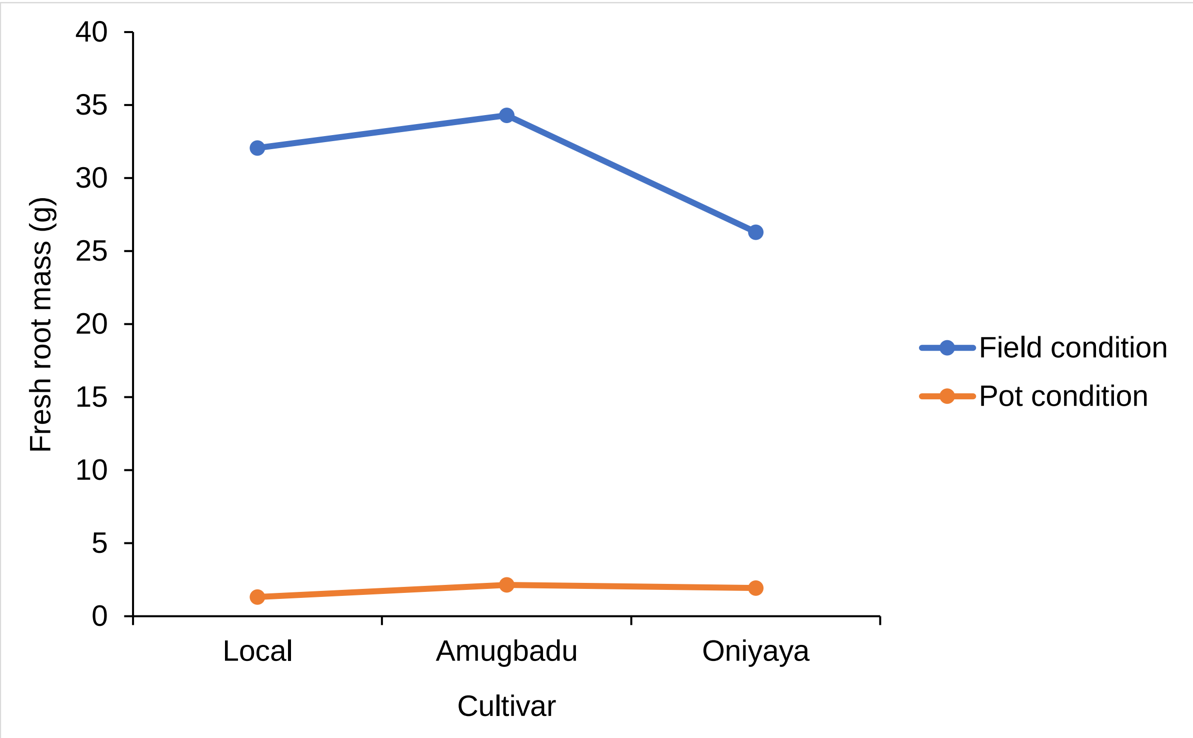


Figure 4.25: Effect of cultivar and growing condition on fresh root mass (g) of *C. olitorius* at 6 WAT

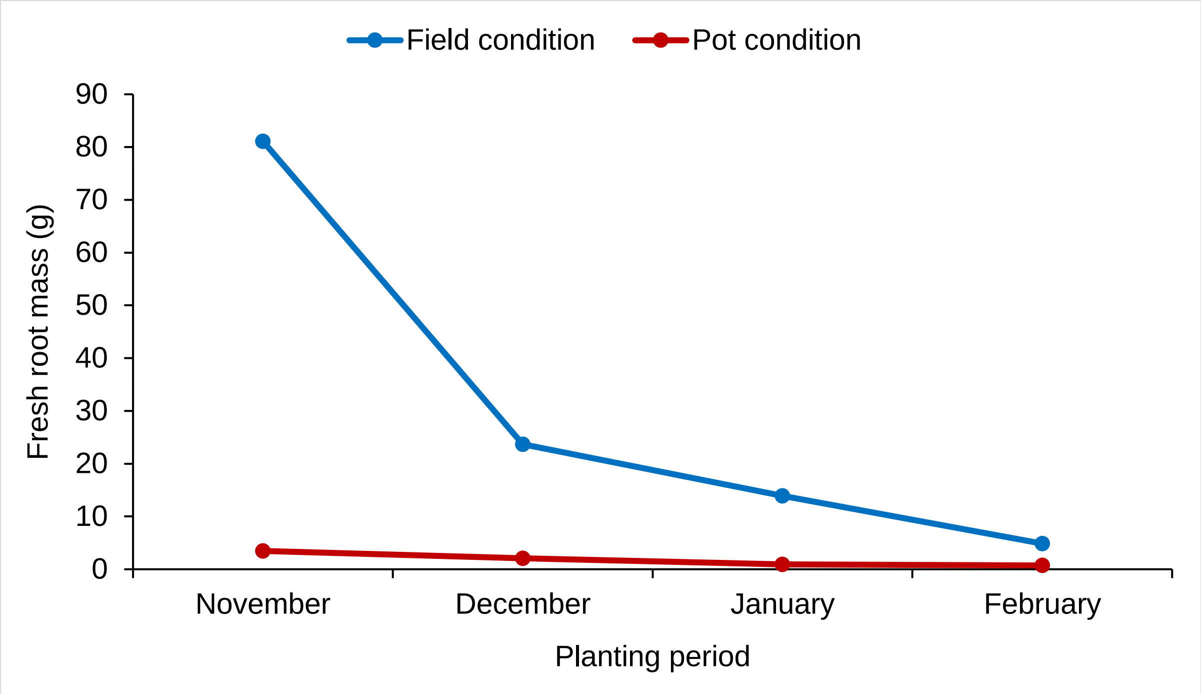


Figure 4.26: Effect of planting period and growing condition on fresh root mass (g) of *C. olitorius* at 6 WAT

4.4.4 Dry root biomass

The combined effect of cultivar, planting period and growing condition did not significantly ($P \leq 0.05$) affect dry root mass of *C. olitorius* (Appendix 4.41). Similar trend was also observed for combined effect of cultivar and planting period on dry root mass (Table 4.11). However, significant ($P < 0.01$) combined influence of cultivar and growing condition on dry root mass of Jew's mallow was obtained at 6 WAT (Figure 4.27). The significantly highest average Jew's mallow dry root mass was obtained in Amugbadu cultivar under field condition whereas under pot conditions Oniyaya produced the highest average dry root mass compared to the other cultivars. In terms of combined effect of planting period and growing condition, highly significant ($P < 0.001$) effect on Jew's mallow dry root mass was recorded (Appendix 4.41). Significantly, highest average Jew's mallow dry root mass was obtained in December period under field conditions while February planting period resulted in the least significant dry root mass (Figure 4.28). Cultivars differed significantly ($P < 0.05$) in terms of dry root mass. The highest average at 6 WAT dry root mass (3.19 g) was obtained in Amugbadu cultivar compared to 2.32 g and 2.38 g obtained in Local and Oniyaya cultivars, respectively (Table 4.11). The differences may be attributed to physiological dissimilarities in accumulation of biomass among the cultivars. The significantly (P < 0.001) highest average dry root mass value was obtained in December planting period (4.38 g) at 6 WAT, while the least significant values were obtained in February planting period (Table 4.11). Averagely high maximum and minimum temperatures during December planting period could be linked to the rate of dry matter accumulation; Jew's mallow is a summer and heat demanding crop. According to Shiwachi *et al*., (2008), in traditional Jew's mallow cultivation, the growers usually sow seeds in different times, but optimum sowing time plays very important role for higher yield.

Table 4.11: Effect of cultivar and planting period on dry root mass (g) of *C. olitorius*

	Weeks after transplanting		
Treatment	6	18	Mean
Cultivar			
Local	2.32b	13.59b	7.96
Amugbadu	3.19a	18.56a	10.88
Oniyaya	2.384b	16.59ab	9.49
Mean	2.63	16.25	9.44
Planting Period			
November	2.71b	20.36a	11.53
December	4.38a	25.53a	14.96
January	2.44b	14.24b	8.34
February	0.99c	4.87c	2.93
Mean	2.63	16.25	9.44
P-values			
Planting Period* Cultivar	0.109^{ns}	0.196^{ns}	
Cultivar	0.000***	0.034*	
Planting Period	0.000***	0.000***	

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

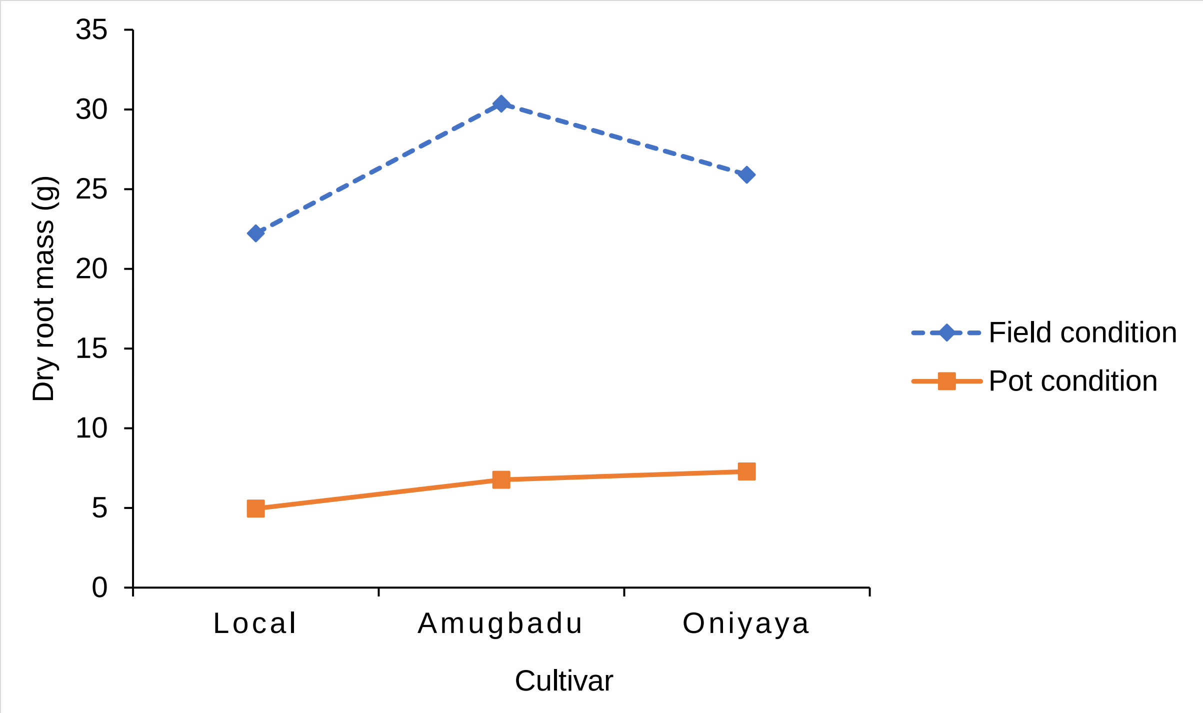


Figure 4.27: Effect of cultivar and growing condition on dry root mass (g) of *C. olitorius* at 6 WAT

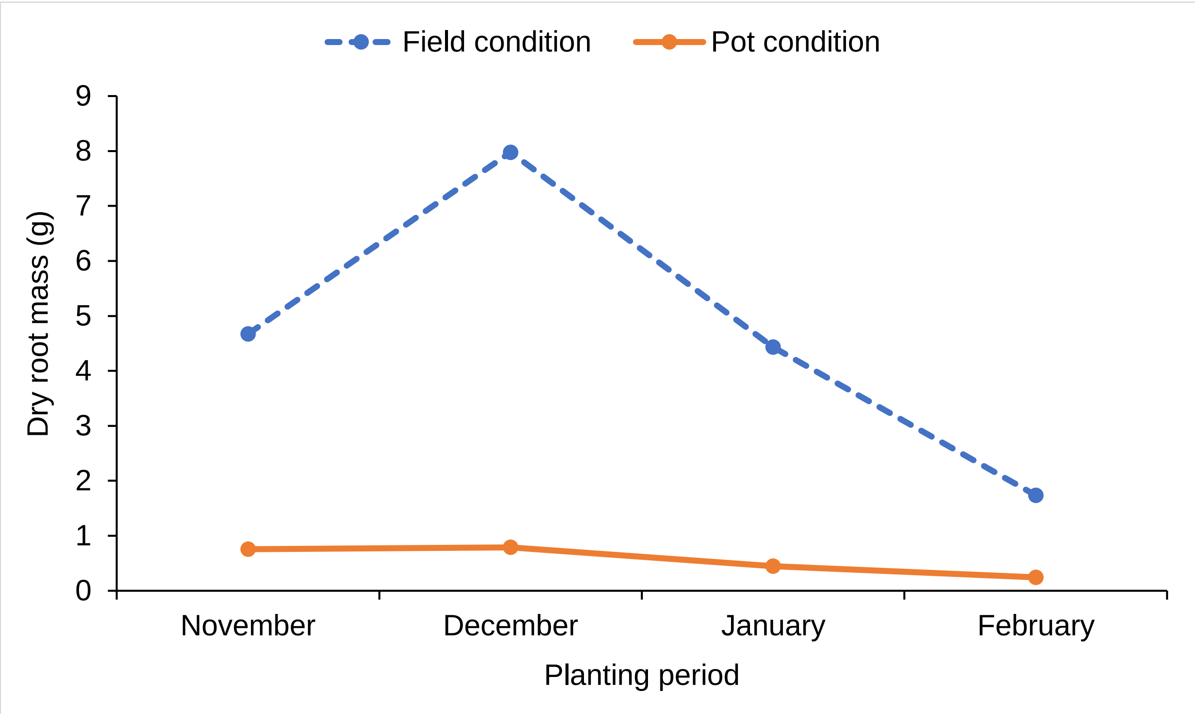


Figure 4.28: Effect of planting period and growing condition on dry root mass (g) of *C. olitorius* at 6 WAT

4.5 Effect of cultivar, planting period and growing condition on seed yield and yield components of three *C. olitorius* cultivars

4.5.1 Flowering

The combined effect of cultivar, planting date and growing condition had a significant ($P < 0.01$) influence on number of days to 50% flowering of *C. olitorius* (Appendix 4.50). The longest average number of days to 50% flowering was observed in Oniyaya and Amugbadu cultivars during November period under field condition, whereas the least average values were observed in all cultivars transplanted during February period regardless of the growing condition (Figure 4.29). Indicating that the season was warmer for longer, hence prolonged vegetative growth for crops grown during the November planting period compared to the February planting period. The Local cultivar flowered earlier than the exotic ones throughout the planting periods under both field and pot conditions. Furthermore, late (February planting period) resulted also in early flowering compared to November and December planting periods. Cultivar and planting period had a significant ($P < 0.01$) effect on Jew's mallow number of days to 50% flowering (Appendix 4.50). The Oniyaya and Amugbadu cultivars, had the same maximum number of days to 50% flowering during November period (Figure 4.30). The planting period and growing condition combined effect significantly ($P < 0.05$) influenced number of days to 50% flowering in Jew's mallow (Figure 4.31). The highest average value was obtained in November and lowest mean values in February planting period under both growing conditions.

The highly significant ($P < 0.001$) lowest average number of days to 50% flowering (55 days) was observed in Local cultivar and there were no significant differences between the other two cultivars with higher values (63.58 and 63.75 days) for Amugbadu and Oniyaya respectively (Table 4.12). This denotes that it took significantly shorter days for Local cultivar to flower as compared to the others. The physiological differences among cultivars in terms of length of vegetative growth stage might have resulted in the Local cultivar reaching reproductive stage earlier than the other cultivars. The highest significant average number of days to 50% flowering was obtained during November period (75 days) and the highly significant ($P < 0.001$) lowest average number of days (48 days) was recorded during February period (Table 4.12). Transplanting *C. olitorius* in February exposes the crop to reduced sunshine hours as the daytimes get shorter in autumn and crops experience lower than ideal temperatures for an extended time during growing period. The sunshine hours were also lower in February (7.6 hrs) compared to (8.7 hrs) in December (Figure 3.9). Thus, shorter vegetative growth period and earlier flowering in *C. olitorius* in February planting period. The findings agree with Sajo and Mohammed (2004) who reported that number of days to 50% flowering was shortened with delayed planting.

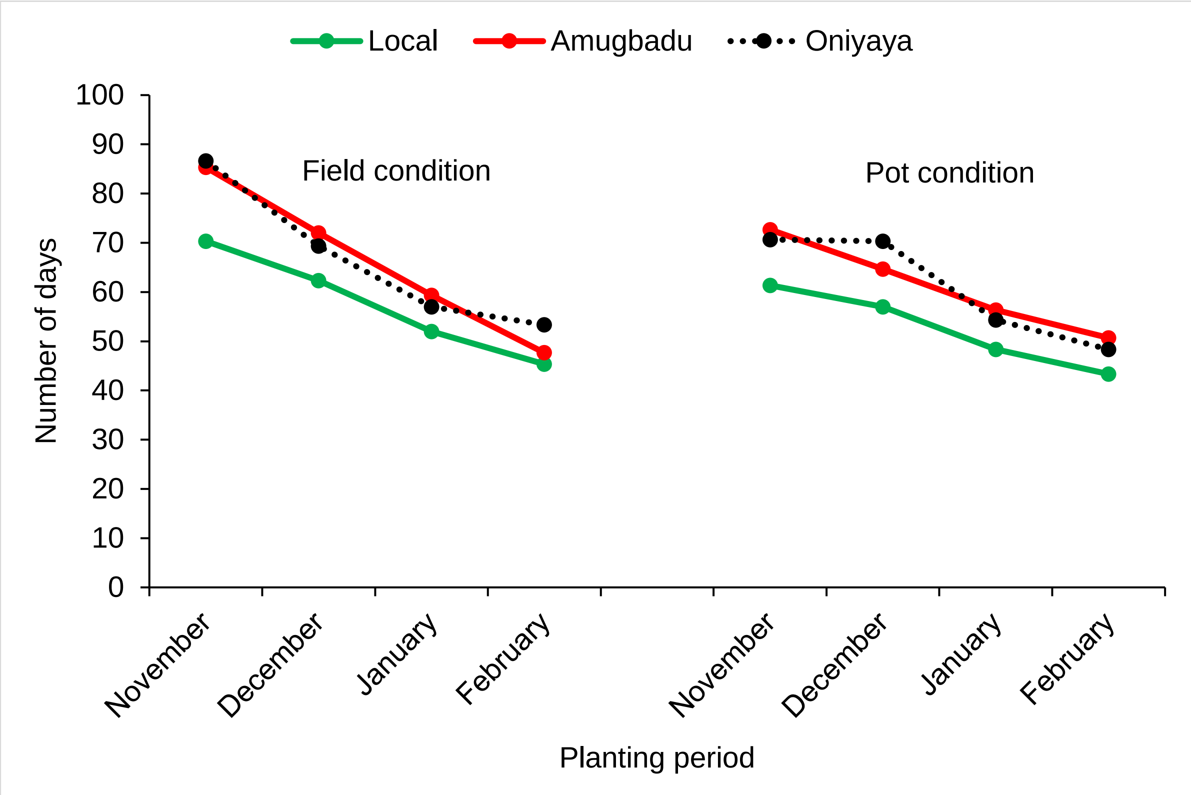


Figure 4.29: Effect of cultivar, planting period and growing condition on number of days to 50% flowering of *C. olitorius*

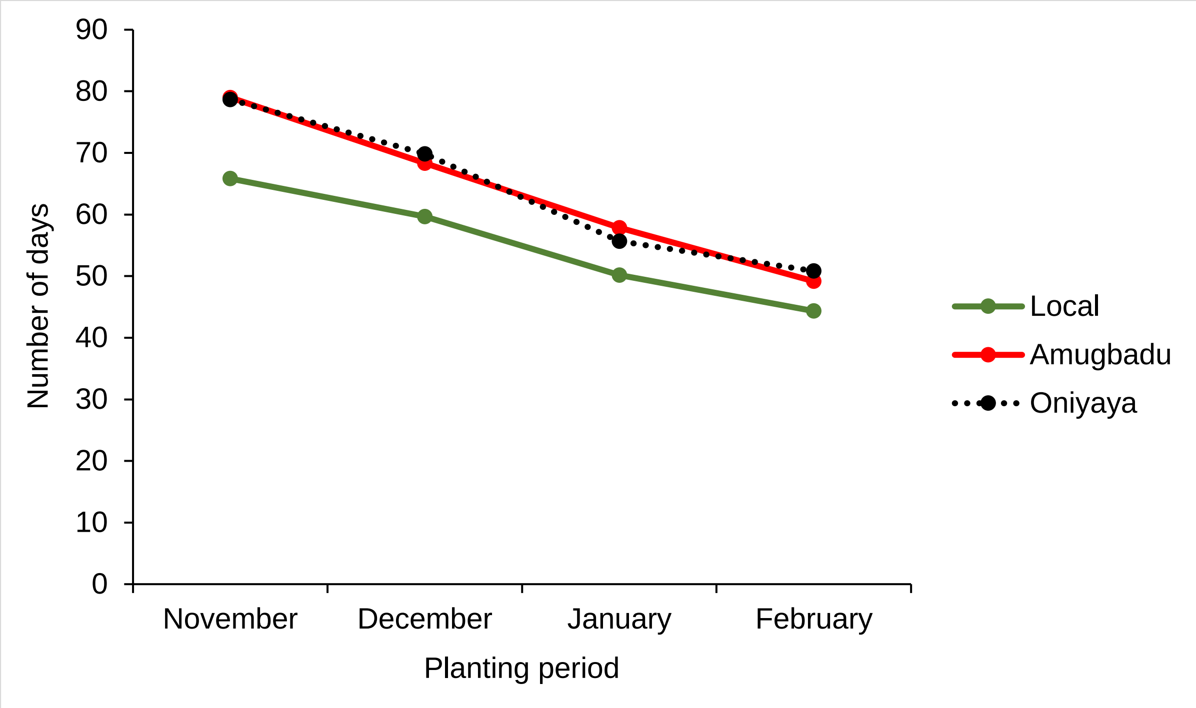


Figure 4.30: Effect of cultivar and planting period on number of days to 50% flowering of *C. olitorius*

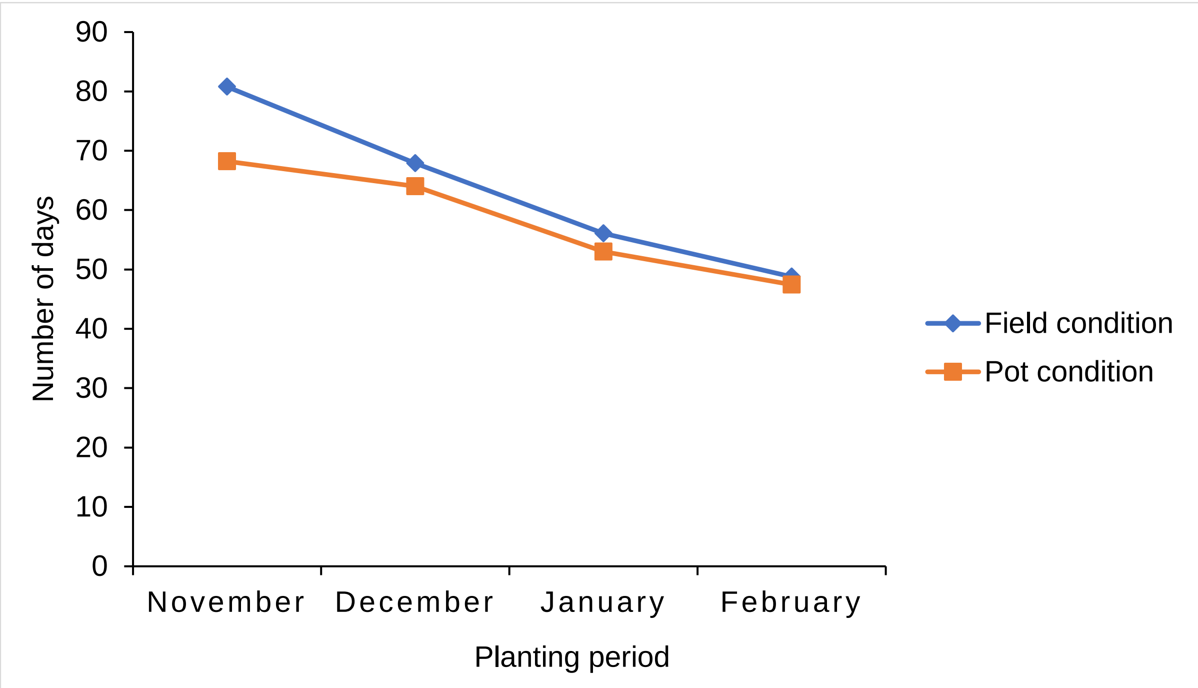


Figure 4.31: Effect of planting period and growing condition on number of days to 50% flowering of *C. olitorius*

Table 4.12: Effect of cultivar and planting period on number of days to flowering of *C. olitorius*

Treatment	No. of days to flowering	No. of days to 50% flowering
Cultivar		
Local	40.21b	55.00b
Amugbadu	46.67a	63.58a
Oniyaya	48.13a	63.75a
Mean	45.00	60.78
Planting Period		
November	53.17a	74.50a
December	46.50b	65.94b
January	44.78b	54.56c
February	35.56c	48.11d
Mean	45.00	60.78
P-values		
Planting Period* Cultivar	0.194^{ns}	0.003**
Cultivar	0.000***	0.000***
Planting Period	0.000***	0.000***

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

4.5.2 Pod formation and seed yield

Cultivar, planting period and growing condition had a significant (P < 0.05) influence on both number of days to 50% pod formation (Appendix 4.51) and number of days to 50% pod maturity of Jew’s mallow (Appendix 4.52). The significantly longest mean numbers of days to 50% pod formation and maturity were observed in Amugbadu and Oniyaya cultivars during November and December period under both growing conditions, while the least average values were obtained in the Local cultivar (Figure 4.32 and Figure 4.33). Thus, the Local cultivar produced pods and the pods mature earlier than the other two cultivars. This follows a similar trend to days to 50 % flowering as reported under 4.5.1. The combined effect of cultivar and planting period significant (P < 0.05) least average number of days to 50% pod formation and maturity was obtained in Local cultivar during February planting period (Figures 4.34 and 4.35).

Hence similar trend to number of days to 50 % flowering. Moreover, highly significant ($P < 0.001$) variation was observed among the cultivars and planting periods in relation to number of days to 50% pod formation and maturity (Appendices 4.51 and 4.52)

The significantly lowest numbers of days to 50% pod formation and maturity obtained from Local cultivar during February period, indicated that the cultivar was better acclimated to environmental conditions in the study area than Oniyaya and Amugbadu. Thus, this could be an advantage for improvement of indigenous cultivars of *C. olitorius* in the Province or even the region. According to Yarnia (2010), it was emphasised that if the right planting date is chosen, a cultivar with a sufficient growth period can flower and generate seed in a timely manner. The Local cultivar thus produced matured pods timely.

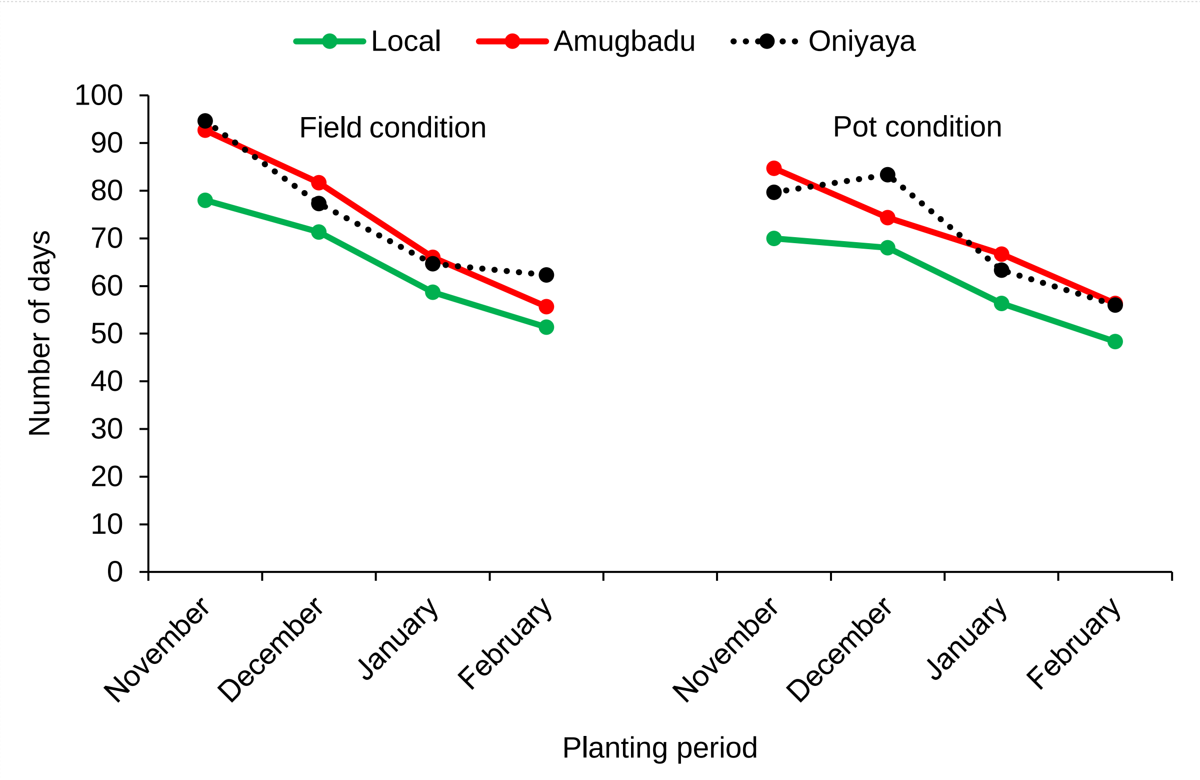


Figure 4.32: Effect of cultivar, planting period and growing condition on number of days to 50% pod formation of *C. olitorius*

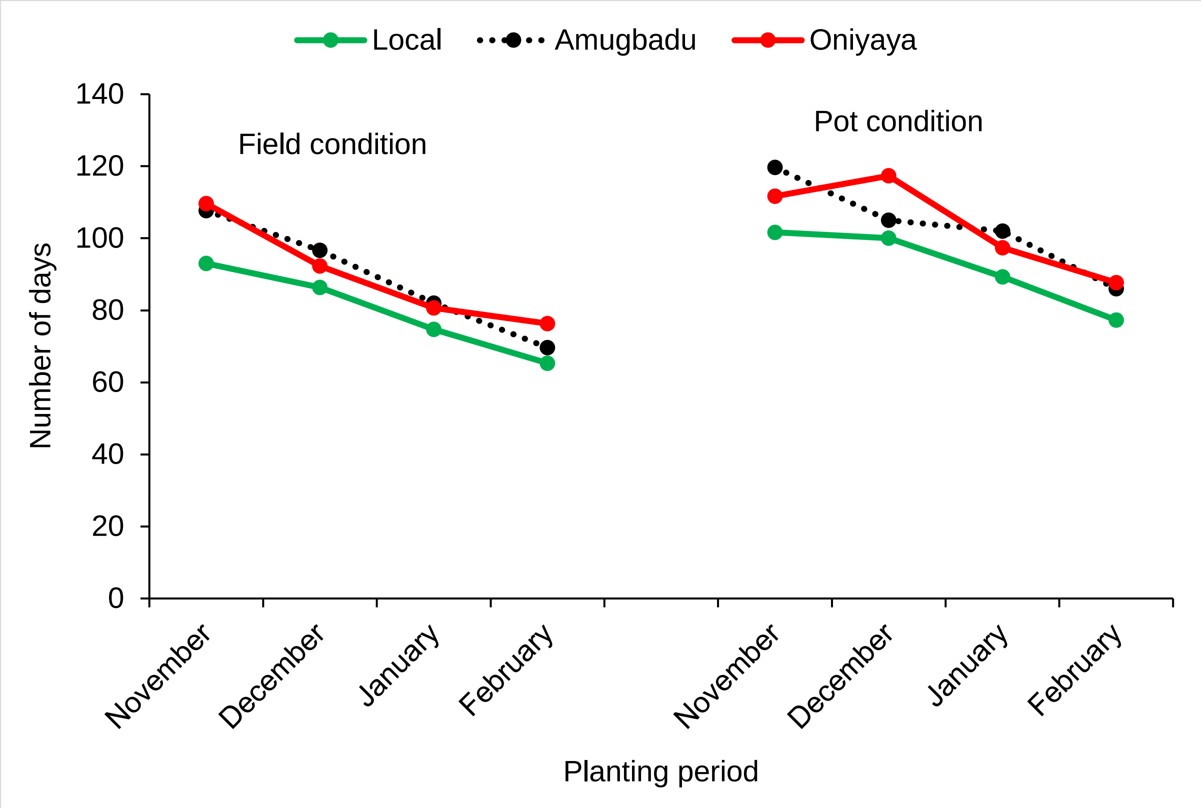


Figure 4.33: Effect of cultivar, planting period and growing condition on number of days to 50% pod maturity of *C. olitorius*

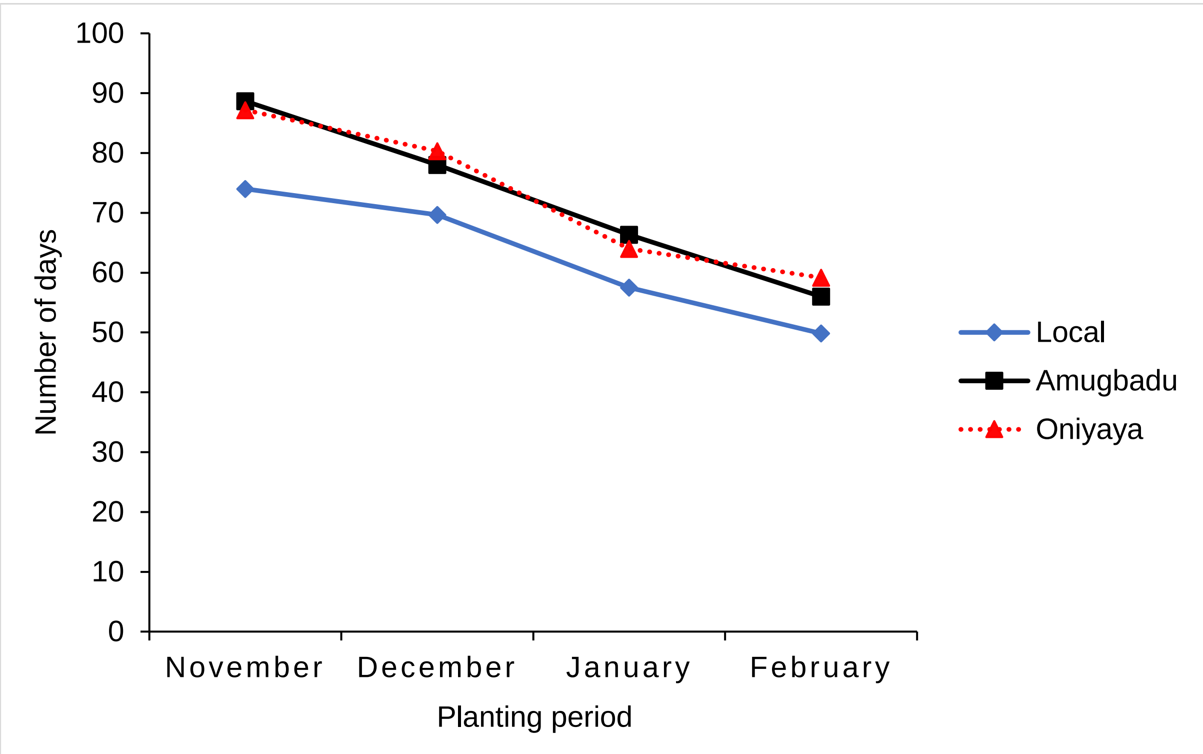


Figure 4.34: Effect of cultivar and planting period on number of days to 50% pod formation of *C. olitorius*

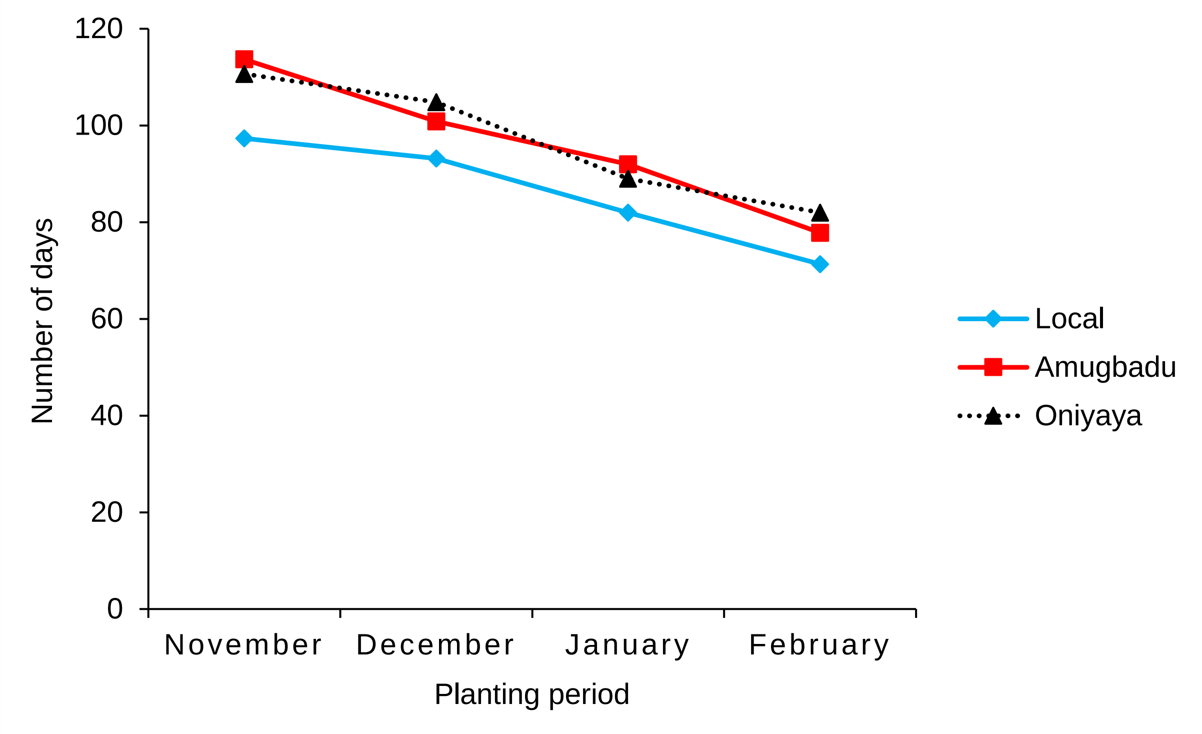


Figure 4.35: Effect of cultivar and planting period on number of days to 50% pod maturity of *C. olitorius*

The combined effect of cultivar, planting period and growing condition had no significant (P ≤ 0.05) influence on number of pods (Appendix 4.53), pod weight (Appendix 4.54) and seed yield (Appendix 4.55) of *C. olitorius*. Furthermore, no significant combined effect (P ≤ 0.05) was recorded due to cultivar and planting period; cultivar and growing condition; planting period and growing condition on number of pods, pod weight and seed yield of *C. olitorius* (Appendices 4.53 to 4.55). The differences observed among cultivars in relation to pod weight of *C. olitorius* were not also significantly (P ≤ 0.05) different. However, the cultivars varied significantly (P < 0.05) in terms of number of pods and seed yield (Table 4.13). The significantly highest average values for number of pods per plant and seed yield were obtained in the Local cultivar. It is notable without doubt that since the cultivars were morphologically different, their yielding patterns and comparative weights might also differ. The Local cultivar may be better acclimated to the environmental conditions in the study site. Jew's mallow number of pods, pod weight and seed yield had highly significant (P < 0.001) variation based on planting period (Table 4.13). The significantly highest means for number of pods per plant, pod weight and seed yield were obtained during

November period whereas the least significant values were obtained during February period.

This superior yield during November period occurs at a time when the minimum and maximum temperatures was adequate for the crop, with moderate sunshine hours and humidity. The drop in recorded wind speed around February might had effect on pollination leading to substantial reduction in fruiting over time (Figure 3.10). From the seed yield perspective, the results suggest that planting be restricted to November and December so that the crop can enjoy optimum temperatures during its growth. The appropriate sowing time is an important agronomic practice which deals with the increment of yield (Hossain *et al*., 2015). According to Akter *et al.* (2017), planting time has a significant impact on light intensity, photoperiod, day and night temperature, and consequently on flower initiation, fruiting, yield, and quality of crops. Seed is one of the most essential factors affecting the crop's productivity. Effective adjustments of yield attributing features that have a favourable influence to seed yield can boost the potential of the Jew’s mallow crop (Talukder, 2001). Gosh *et al*. (2018) recommended adjustment to early sowing to improve total seed yield in Jew’s mallow.

Table 4.13: Effect of cultivar and planting period on number of pods, pod weight and seed yield of *C. olitorius*

Treatment	No. of pods Per plant	Pod weight (g)	Seed yield (g)
Cultivar			
Local	54.54a	54.42a	2.82a
Amugbadu	41.92b	44.95a	2.20b
Oniyaya	45.08ab	43.78a	2.25ab
Mean	47.18	47.72	2.43
Planting Period			
November	66.33a	97.27a	3.59a
December	48.44b	41.49b	2.45b
January	43.72bc	29.21c	2.05bc
February	30.222c	22.90c	1.62c
Mean	47.18	47.72	2.43
P-values			
Planting Period* Cultivar	0.508^{ns}	0.600^{ns}	0.240^{ns}
Cultivar	0.022*	0.099^{ns}	0.022*
Planting Period	0.000***	0.000***	0.000***

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

4.6 Effect of cultivar, planting period and growing condition on nutritional composition of three *C. olitorius* cultivars

Cultivar, planting period and growing condition had no significant effect (P ≤ 0.05) on Copper (Appendix 4.56), Nitrogen (Appendix 4.61), Calcium (Appendix 4.62), Magnesium (Appendix 4.63), Potassium (Appendix 4.64), Sodium (Appendix 4.65) and dry matter (Appendix 4.68) contents of *C. olitorius*. However, significant (P < 0.05) combined effect of the three treatment factors was observed on the amount of Zinc in *C. olitorius* (Appendix 4.66). There appears to be no distinct interactive pattern of the three factors on the Zinc content of *C. olitorius.* For example, significantly highest average amount of Zinc was obtained in Oniyaya cultivar during February planting whereas the lowest amount was recorded from Local cultivar during the same period under pot condition (Figure 4. 36). In terms of combined effect of cultivar and growing condition; planting period and growing condition on Cu, N, Ca, Mg, K, Na, Zn and dry matter of *C. olitorius* the differences observed were not significant ($P \leq 0.05$). Nevertheless, interaction between cultivar and planting period significantly ($P < 0.05$) influenced N, Ca, Mg and K contents of *C. olitorius* (Table 4.14). The highest average amounts of N (Figure 4.37), Mg (Figure 4.39) and K (Figure 4.40) were obtained from Local cultivar during November period while Local cultivar produced the highest average amount of Ca during December period (Figure 4.38).

While cultivar had no significant ($P \leq 0.05$) effect on Mg (Table 4.14), Na (Appendix 4.65), Zn (Appendix 4.66) and dry matter contents of *C. olitorius* (Appendix 4.68); significant ($P < 0.05$) differences were recorded in Cu N, Ca and K contents of *C. olitorius* (Table 4.14). The greatest average amounts of N and Ca were obtained in Local cultivar while that of K and Cu were recorded in Oniyaya cultivar. The N, Ca, Mg, K and Cu contents of *C. olitorius* varied significantly ($P < 0.01$) with planting period. The highest mean values of N, Mg, K and Cu were obtained during December period and that of Ca in *C. olitorius* was obtained in November planting period (Table 4.14). The overall vegetative growth was best obtained during November planting period which might be responsible for better nutritional composition of Jew's mallow grown during this period.

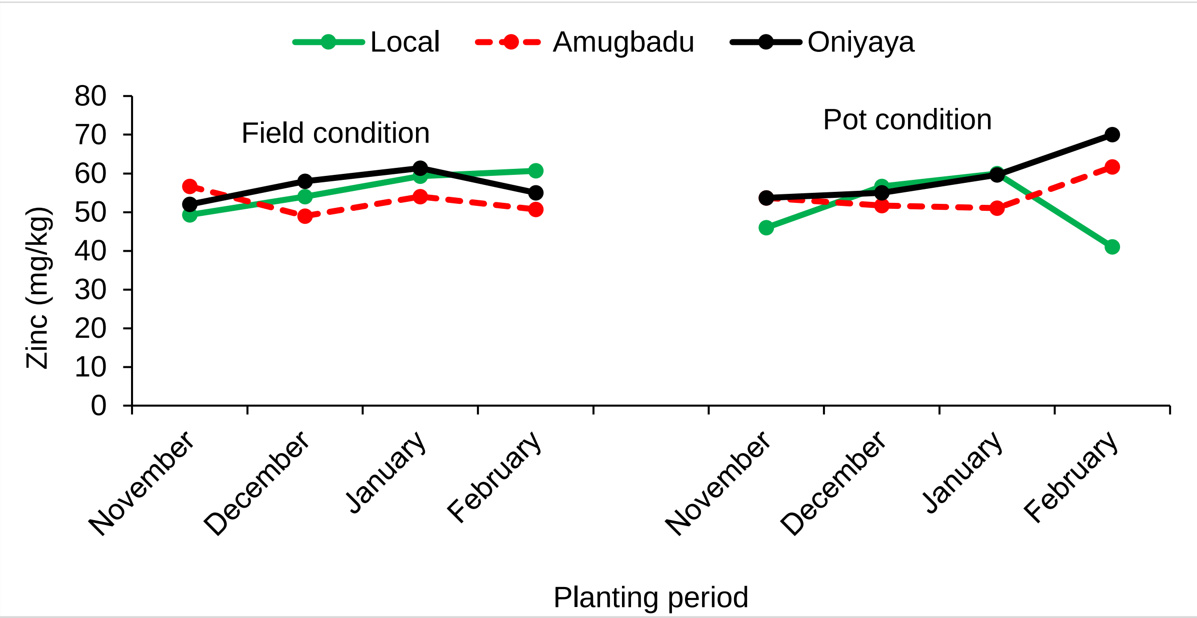


Figure 4.36: Effect of cultivar, planting period and growing condition on Zinc (mg/kg) of *C. olitorius* at 6 WAT

Table 4.14: Effect of cultivar and planting period on nutritional composition of *C. olitorius*

Treatment	Nutrient elements				
	N (%)	Ca (%)	Mg (%)	K (%)	Cu (mg/kg)
Cultivar					
Local	4.74a	2.37a	0.34a	3.76ab	10.26c
Amugbadu	4.22c	2.06b	0.35a	3.71b	11.30b
Oniyaya	4.51b	2.04b	0.35a	3.97a	12.19a
Mean	4.49	2.15	0.35	3.81	11.25
Planting period					
November	5.42a	1.92b	0.43a	4.63a	12.66a
December	3.90c	2.29a	0.30c	3.32b	9.38c
January	4.28b	2.23a	0.33bc	3.60b	11.38b
February	4.37b	2.18a	0.34b	3.69b	11.57ab
Mean	4.49	2.15	0.35	3.81	11.25
P-values					
Planting period* Cultivar	0.006**	0.009**	0.012*	0.001**	0.782^{ns}
Cultivar	0.000***	0.000***	0.610^{ns}	0.017*	0.000***
Planting period	0.000***	0.001***	0.000***	0.000***	0.000***

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

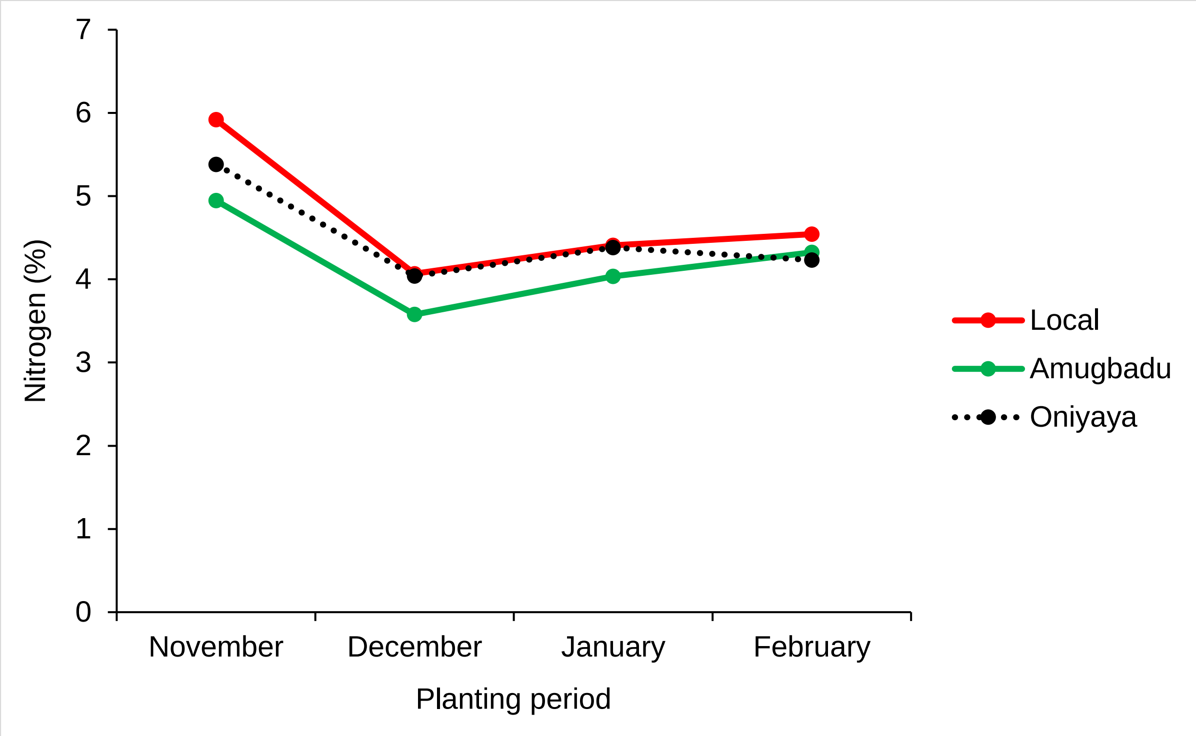


Figure 4.37: Effect of cultivar and planting period on Nitrogen (%) of *C. olitorius* at 6 WAT

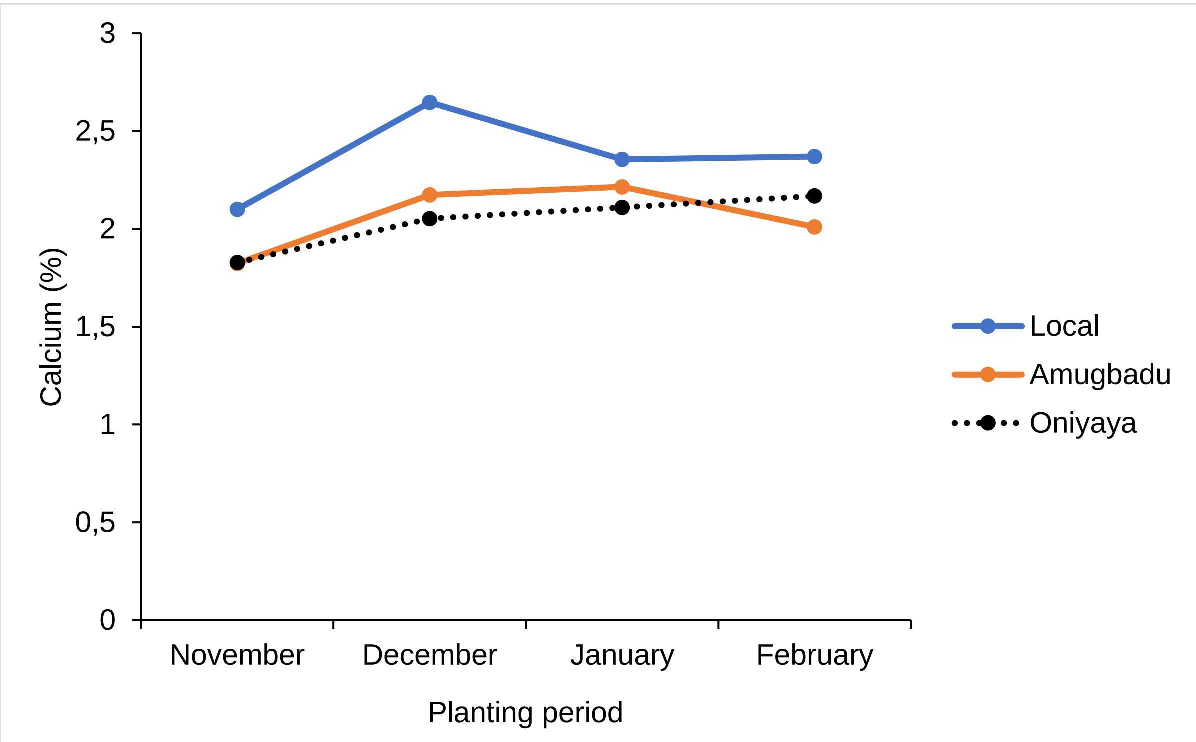


Figure 4.38: Effect of cultivar and planting period on Calcium (%) of *C. olitorius* at 6 WAT

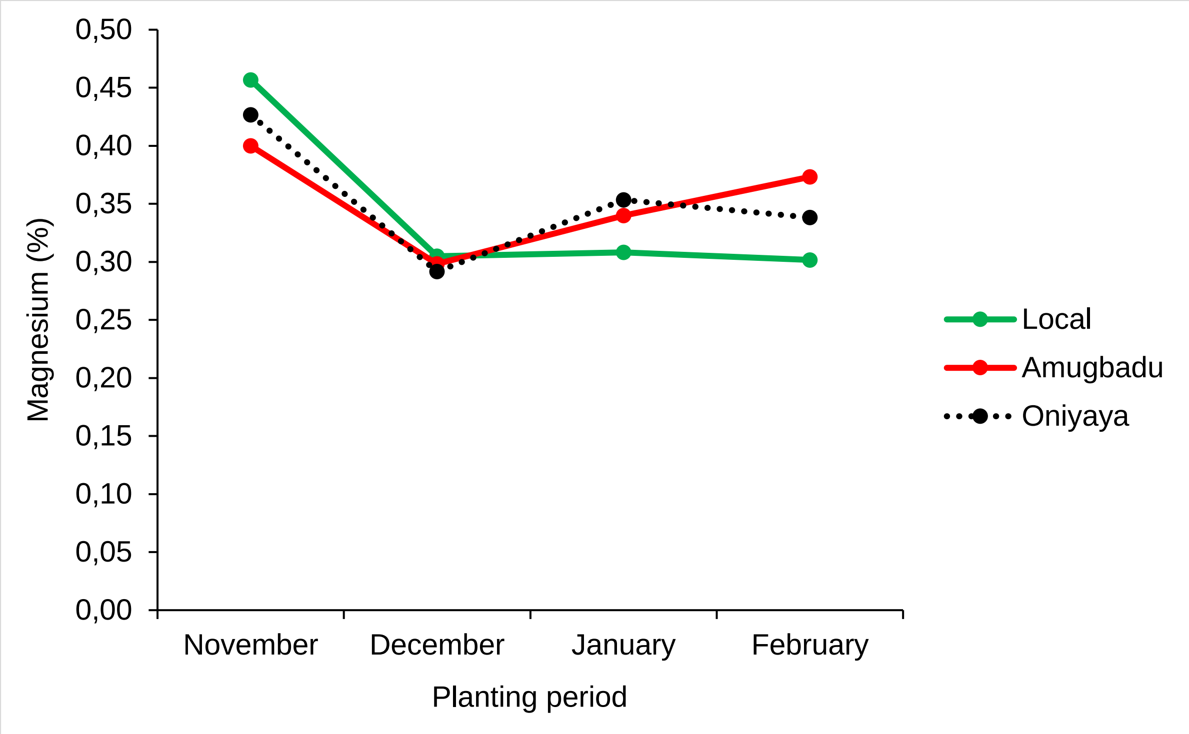


Figure 4.39: Effect of cultivar and planting period on Magnesium (%) of *C. olitorius* at 6 WAT

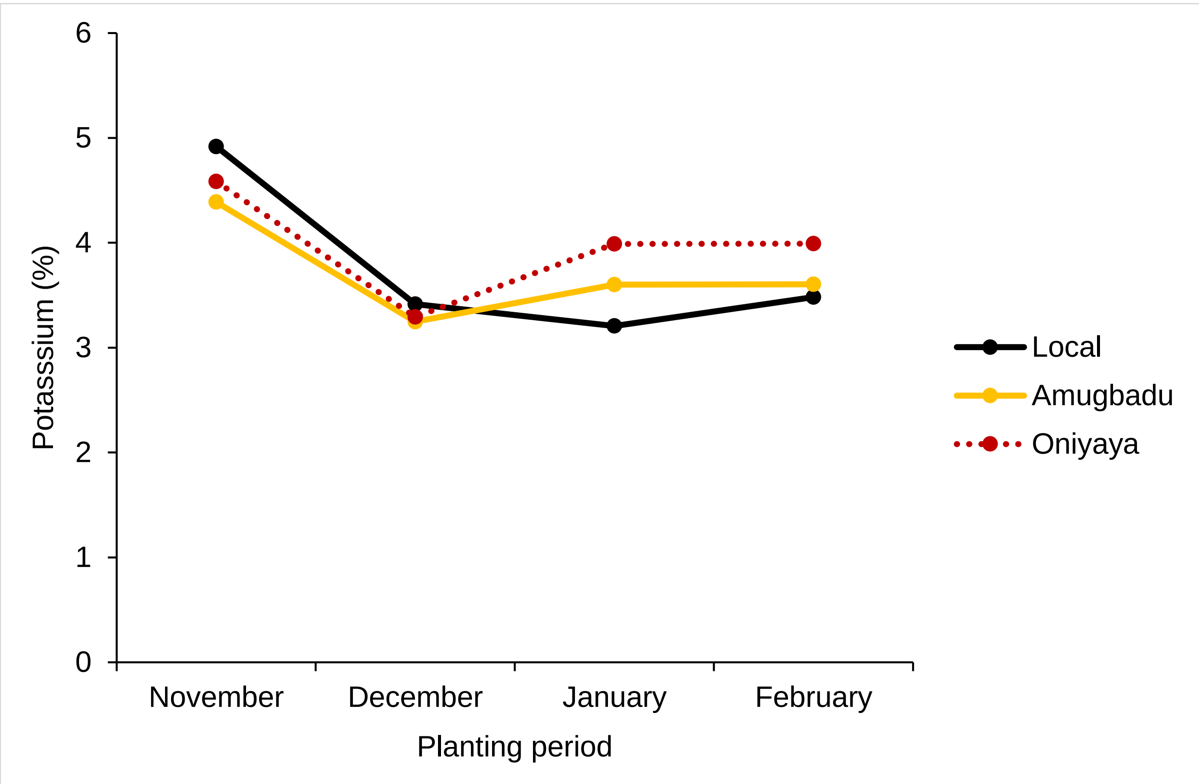


Figure 4.40: Effect of cultivar and planting period on Potassium (%) of *C. olitorius* at 6 WAT

The combined effect of cultivar, planting period and growing condition had no significant ($P \leq 0.05$) influence on Manganese (Appendix 4.57), Iron (Appendix 4.58), Phosphorus 4.59), Aluminium (Appendix 4.60) and ash (Appendix 4.67) contents of *C. olitorius*. Similar non-significant ($P \leq 0.05$) interactive effect between cultivar and growing condition on Mn, Fe, P, Al and ash contents of *C. olitorius* were observed. Cultivar and planting period had significant influence ($P < 0.05$) on Mn contents of *C. olitorius* (Figure 4.41), whereas P content of *C. olitorius* was only significantly influenced by combined effect of planting period and growing condition (Figure 4.42). Thus, the variation observed in P contents of *C. olitorius* was more dependent on the planting period and growing condition rather than the cultivar. The significantly highest average amount of Mn was obtained in Local cultivar during February period and in Amugbadu and Oniyaya during November period (Figure 4.41). Phosphorus contents of *C. olitorius* were highest and lowest under field condition during November and February planting periods, respectively (Figure 4.42).

Regarding the cultivars significant ($P < 0.05$) differences were obtained in Mn, P and Al contents of Jew's mallow with the highest average amounts recorded in the Local cultivar (Table 4.15). This cultivar may be naturally more nutritive than Oniyaya and Amugbadu cultivars. The planting period also significantly ($P < 0.05$) affected Mn, Fe, P, Al and ash contents of *C. olitorius* and the greatest average amounts were obtained during November period (Table 4.15). This may be attributed to differences in temperature during different planting periods which may play a substantial role in accumulation of these elements. To produce *C. olitorius* with high nutritional composition in Limpopo Province, the agronomic practice of planting period must be managed such that crop establishment of any of the three cultivars on the field is carried out during the November planting period. Thus, planting Jew's mallow in December or later months might result in reduced nutritive quality of the crop. According to Nam *et al*. (1995), when plants are exposed to extreme temperatures, several physiological and biochemical processes are changed, resulting in alterations in chemical composition. The severity of these alterations is mostly determined by the temperature, the length of exposure to the temperature, and the stage of plant development (Yarnia, 2010).

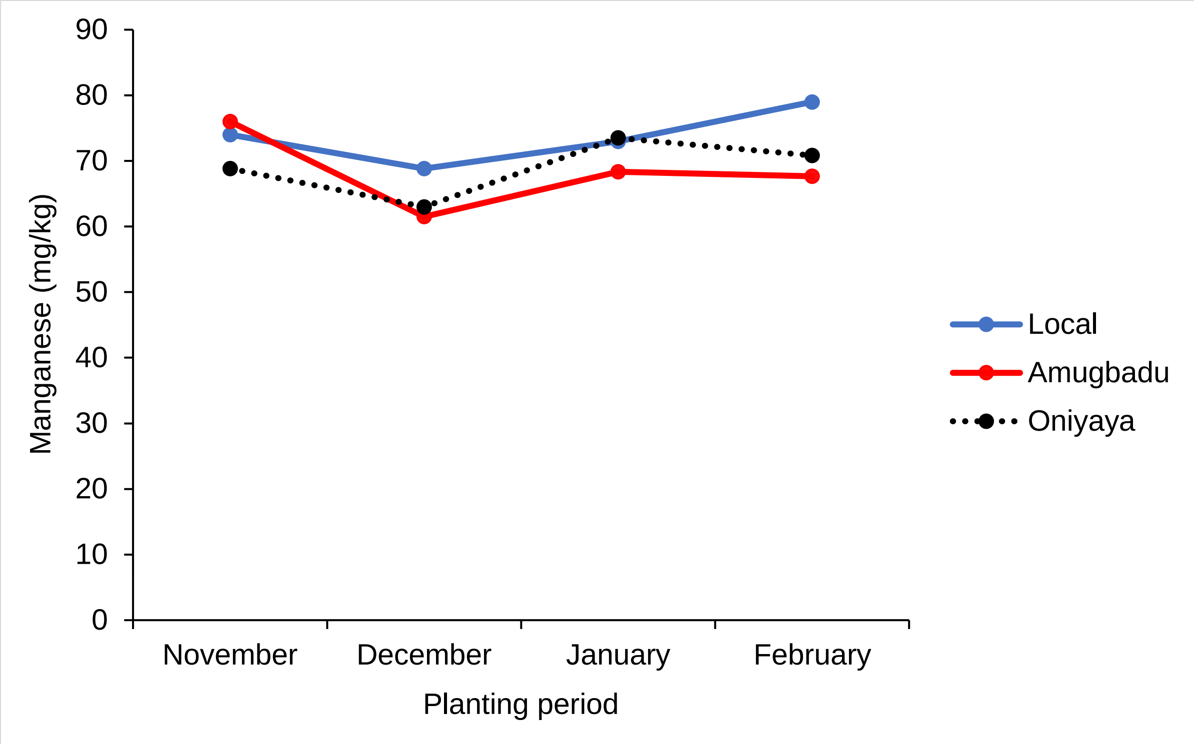


Figure 4.41: Effect of cultivar and planting period on Manganese (mg/kg) of *C. olitorius* at 6 WAT

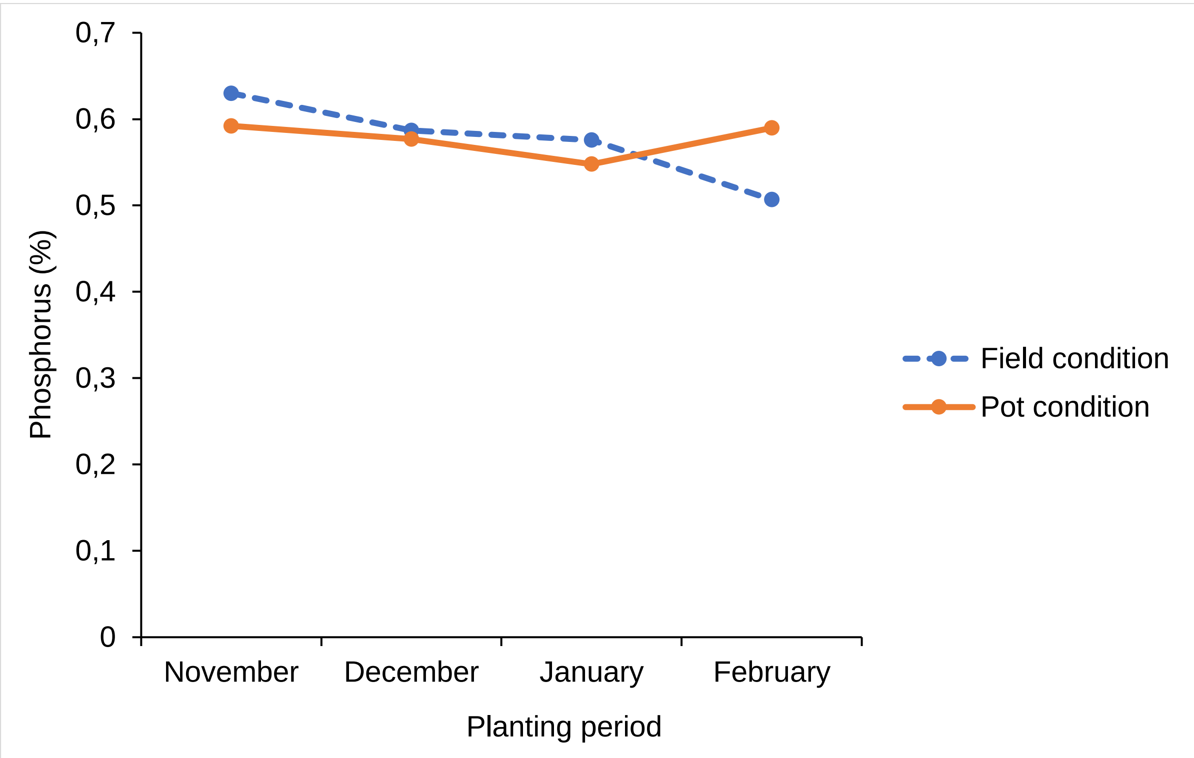


Figure 4.42: Effect of planting period and growing condition on Phosphorus (%) of *C. olitorius* at 6 WAT

Table 4.15: Effect of cultivar and planting period on nutritional composition of *C. olitorius*

Treatment	Nutrient elements				
	Mn (mg/kg)	Fe (mg/kg)	P (%)	Al (mg/kg)	Ash (%)
Cultivar					
Local	73.71a	504.75a	0.57ab	494.25a	11.74a
Amugbadu	68.38b	647.67a	0.56b	651.12a	12.60a
Oniyaya	69.04b	639.88a	0.57ab	661.33a	12.88a
Mean	70.38	597.43	0.57	602.23	12.41
Planting period					
November	72.94a	1319.60a	0.61a	1344.30a	17.33a
December	64.44b	287.20b	0.58ab	299.10b	9.22b
January	71.61ab	405.60b	0.56ab	393.20b	10.94b
February	72.50a	377.30b	0.55b	372.40b	12.13b
Mean	70.37	597.43	0.58	602.25	12.41
P-values					
Planting period* Cultivar	0.050*	0.369^{ns}	0.200^{ns}	0.306^{ns}	0.141^{ns}
Cultivar	0.004**	0.1400^{ns}	0.010*	0.052*	0.401^{ns}
Planting period	0.027*	0.000***	0.051^{*}	0.000***	0.000***

Means followed by the same letter in a column are not significantly different at P ≤ 0.05, ns, *, **, ***, means: non-significant or significant at P≤ 0.05, 0.01, 0,001 respectively

4.7 Correlation between *C. olitorius* parameters

In *C. olitorius* the results show that there were positive correlations between all the growth parameters assessed in this study. Mucilage content significantly and positively correlated with fresh shoot mass (0.569*), number of branches (0.594*), number of leaves (0.595*), and plant height (0.607*) (Table 4.16). Also significant positive correlation between chlorophyll content and leaf area (0.572*). Number of branches significant positive correlations with number of leaves (0.951*) fresh shoot mass (0.881*), plant height (0.840*) and stem diameter (0.638*) were also obtained. Furthermore, number of leaves had a significant positive correlation with fresh shoot mass (0.903*), plant height (0.845*) and stem diameter (0.609*). Plant height also had a significant positive correlation with fresh shoot mass (0.888*). The correlations between mucilage content and chlorophyll content (R^2= 0.020) and leaf area of *C. olitorius* (R^2= 0.070) were positive but weak. There was also positive but weak correlation between chlorophyll content and number of branches, number of leaves, plant height, stem diameter and fresh shoot biomass. For all the parameters there was none with negative correlation. The fresh shoot mass is the marketable yield of the crop. Hence, the strong positive correlations with mucilage content (0.569*), number of branches (0.881*), number of leaves (0.903*), and plant height (0.888*) means positive association between the parameters that that could be explored further in the improvement of the test crop. The favourable weather conditions for greater part of the study might account for improved vegetative growth hence the shoot mass. The findings from this study agree with those of Ullah *et al*. (2013) who reported that optimum planting time ensures proper growth of plant and consequently the plant weight.

Table 4.16: Correlation coefficients (r) between *C. olitorius* parameters

	Mucilage content (mPa·s)	Chlorophyll content (cci)	# of branches	# of leaves	Plant height (cm)	Stem diameter (mm)	Leaf area (cm^2)	Fresh shoot biomass (g)
Mucilage content								
Chlorophyll content	0.020							
# of branches	0.594*	0.338						
# of leaves	0.595*	0.235	0.951*					
Plant height	0.607*	0.202	0.840*	0.845*				
Stem diameter	0.258	0.135	0.638*	0.609*	0.563			
Leaf area	0.070	0.572*	0.346	0.378	0.232	0.071		
Fresh shoot biomass	0.569*	0.218	0.881*	0.903*	0.888*	0.531	0.313	

Significant level * P ≤ 0.05

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

In this study, the effect of cultivar and planting period on growth, yield, mucilage and nutritional composition of three *C. olitorius* cultivars under field and shade house conditions was investigated. The study revealed that transplanting *C. olitorius* in December period led to higher amount of mucilage content regardless of the different growing condition and cultivar. Plant growth *of C. olitorius* such as number of branches, plant height and number of leaves were highest during the December planting period. Similar trend was observed for fresh and dry shoot and root masses of the crop. While highest values for chlorophyll content and leaf area were obtained in November planting period. Highest average number of days to flowering, pod formation, pod dry weight and seed yield were also obtained in November planting period. Similar trend was observed for the nutritional composition of *C. olitorius* with the highest values in terms of N, C, K, Fe, P and ash contents recorded in November planting period. Better growth, yield and yield components were obtained under the field compared to the pot conditions.

Transplanting any of the three cultivars during November period showed differences among the cultivars in terms of higher pod dry weight. November and December planting periods allow *C. olitorius* to reach its maximum growth capacity, translating to higher yield and nutritional composition of *C. olitorius* compared to other planting periods. Local cultivar in December planting period was generally more nutritive than other cultivars in the same period compared to any other planting period. While Oniyaya had consistently higher mucilage and chlorophyll contents; also higher number of leaves and branches compared to others.

5.2 Conclusion

Several inferences can be made from the findings from this study. The mucilage content of *C. olitorius* was optimally produced in December period when the temperatures are at the highest in the area of study. Growth parameters such as chlorophyll content and stem diameter varied among cultivars based on planting periods and different growing conditions. Growth characteristics such as number of branches, plant height and number of leaves were higher in Local and Oniyaya cultivars in December planting period. The Local cultivar flowered at the shortest number of days but produced highest number of pods and seed yield during the December planting period under the field condition. Growth in terms of fresh shoot mass, which is the marketable part of Jew's mallow was best under December planting period, chemical composition of the crop was better attained in November planting period. For best performance in terms of mucilage content, growth, yield and nutritional composition, *C. olitorius* should be grown in November and December periods under the field conditions in the study area.

5.3 Recommendations

It is recommended that any of the three *C. olitorius* cultivars in question can be grown during the December planting period for improved growth, yield and mucilage content. Whereas November planting period was best for nutritional composition of the crop. Therefore, November and December planting periods are best for the production of the crop under the field conditions in the Capricorn district of Limpopo Province. Future research could focus on assessing more local and available cultivars in South Africa for growth, yield and mucilage content over varied ecological zones and planting periods. Also series of assessment for consumer preferences for the purpose of commercialisation of the crop.

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APPENDICES

Appendix 4.1: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stand establishment of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	0.36	0.18		
Growing condition (GC)	1	5618.00	5618.00	19261.71	0.0001
Error Rep*GC	2	0.58	0.29		
Planting period (PP)	3	1.17	0.39	1.42	0.2842
GC*PP	3	0.56	0.19	0.68	0.5821
Error Rep*GC*PP	12	3.28	0.27		
Cultivar (Cv)	2	0.36	0.18	1.53	0.2321
GC*Cv	2	0.58	0.29	2.47	0.1005
PP*Cv	6	0.42	0.07	0.59	0.7371
GC*PP*Cv	6	0.19	0.03	0.27	0.9448
Error Rep*GC*PP*Cv	32	3.78	0.12		
Total	71	5629.28			

Appendix 4.2: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stand establishment of *Corchorus olitorius* at 18 WAT

Source	DF	SS	MS	F	P
Rep	2	0.36	0.18		
Growing condition (GC)	1	5618.00	5618.00	19261.71	0.0001
Error Rep*GC	2	0.58	0.29		
Planting period (PP)	3	1.17	0.39	1.42	0.2842
GC*PP	3	0.56	0.19	0.68	0.5821
Error Rep*GC*PP	12	3.28	0.27		
Cultivar (Cv)	2	0.36	0.18	1.53	0.2321
GC*Cv	2	0.58	0.29	2.47	0.1005
PP*Cv	6	0.42	0.07	0.59	0.7371
GC*PP*Cv	6	0.19	0.03	0.27	0.9448
Error Rep*GC*PP*Cv	32	3.78	0.12		
Total	71	5629.28			

Appendix 4.3: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on mucilage content (mPa·s) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	18703	9351		
Growing condition (GC)	1	155403	155403	7.39	0.1129
Error Rep*GC	2	42058	21029		
Planting period (PP)	3	139220	46407	7.24	0.0050
GC*PP	3	27270	9090	1.42	0.2855
Error Rep*GC*PP	12	76878	6406		
Cultivar (Cv)	2	42563	21282	1.81	0.1805
GC*Cv	2	3940	1970	0.17	0.8467
PP*Cv	6	67587	11264	0.96	0.4699
GC*PP*Cv	6	64733	10789	0.92	0.4963
Error Rep*GC*PP*Cv	32	376928	11779		
Total	71	1015283			

Appendix 4.4: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on mucilage content (mPa·s) of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	1867	933.7		
Growing condition (GC)	1	80000	80000.0	22.81	0.0412
Error Rep*GC	2	7015	3507.3		
Planting period (PP)	3	60735	20244.9	11.69	0.0007
GC*PP	3	16231	5410.2	3.12	0.0661
Error Rep*GC*PP	12	20785	1732.1		
Cultivar (Cv)	2	43478	21738.9	9.64	0.0005
GC*Cv	2	16900	8450.0	3.75	0.0345
PP*Cv	6	20494	3415.7	1.52	0.2049
GC*PP*Cv	6	10778	1796.3	0.80	0.5794
Error Rep*GC*PP*Cv	32	72133	2254.2		
Total	71	350415			

Appendix 4.5: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	1592.2	796.10		
Growing condition (GC)	1	164.2	164.17	477.50	0.0021
Error Rep*GC	2	0.7	0.34		
Planting period (PP)	3	28138.9	9379.63	29.75	0.0000
GC*PP	3	980.3	326.78	1.04	0.4115
Error Rep*GC*PP	12	3783.5	315.29		
Cultivar (Cv)	2	538.6	269.30	14.14	0.0000
GC*Cv	2	1423.1	711.55	37.37	0.0000
PP*Cv	6	1018.1	169.69	8.91	0.0000
GC*PP*Cv	6	2680.3	446.72	23.46	0.0000
Error Rep*GC*PP*Cv	32	609.2	19.04		
Total	71	40929.1			

Appendix 4.6: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	253.9	126.94		
Growing condition (GC)	1	208.8	208.76	108.63	0.0091
Error Rep*GC	2	3.8	1.92		
Planting period (PP)	3	24108.8	8036.25	70.16	0.0000
GC*PP	3	962.4	320.80	2.80	0.0853
Error Rep*GC*PP	12	1374.6	114.55		
Cultivar (Cv)	2	401.4	200.68	13.00	0.0001
GC*Cv	2	1199.5	599.77	38.84	0.0000
PP*Cv	6	1074.8	179.14	11.60	0.0000
GC*PP*Cv	6	2660.3	443.38	28.72	0.0000
Error Rep*GC*PP*Cv	32	494.1	15.44		

Total	71	32742.4

Appendix 4.7: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	145.6	72.82		
Growing condition (GC)	1	137.3	137.31	126.19	0.0078
Error Rep*GC	2	2.2	1.09		
Planting period (PP)	3	14309.0	4769.66	183.27	0.0000
GC*PP	3	831.6	277.20	10.65	0.0011
Error Rep*GC*PP	12	312.3	26.02		
Cultivar (Cv)	2	294.2	147.12	12.16	0.0001
GC*Cv	2	1039.6	519.79	42.98	0.0000
PP*Cv	6	926.5	154.41	12.77	0.0000
GC*PP*Cv	6	1877.0	312.83	25.87	0.0000
Error Rep*GC*PP*Cv	32	387.0	12.09		
Total	71	20262.2			

Appendix 4.8: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	295.47	147.73		
Growing condition (GC)	1	154.76	154.76	34.18	0.0280
Error Rep*GC	2	9.06	4.53		
Planting period (PP)	3	4075.87	1358.62	21.42	0.0000
GC*PP	3	522.91	174.30	2.75	0.0890
Error Rep*GC*PP	12	761.16	63.43		
Cultivar (Cv)	2	249.94	124.97	16.01	0.0000
GC*Cv	2	536.69	268.35	34.37	0.0000
PP*Cv	6	411.19	68.53	8.78	0.0000
GC*PP*Cv	6	1027.44	171.24	21.93	0.0000
Error Rep*GC*PP*Cv	32	249.85	7.81		
Total	71	8294.34			

Appendix 4.9: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	0.17	0.084		
Growing condition (GC)	1	105.37	105.367	185.20	0.0054
Error Rep*GC	2	1.14	0.569		
Planting period (PP)	3	1696.76	565.585	113.26	0.0000
GC*PP	3	375.58	125.195	25.07	0.0000
Error Rep*GC*PP	12	59.92	4.993		
Cultivar (Cv)	2	187.89	93.946	11.63	0.0002
GC*Cv	2	398.02	199.012	24.63	0.0000
PP*Cv	6	381.51	63.585	7.87	0.0000
GC*PP*Cv	6	634.74	105.790	13.09	0.0000
Error Rep*GC*PP*Cv	32	258.60	8.081		
Total	71	4099.70			

Appendix 4.10: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on chlorophyll content of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	92.66	46.331		
Growing condition (GC)	1	89.76	89.758	1270.43	0.0008
Error Rep*GC	2	0.14	0.071		
Planting period (PP)	3	855.46	285.155	14.04	0.0003
GC*PP	3	255.10	85.035	4.19	0.0304
Error Rep*GC*PP	12	243.80	20.316		
Cultivar (Cv)	2	411.01	205.506	22.44	0.0000
GC*Cv	2	219.36	109.679	11.98	0.0001
PP*Cv	6	255.72	42.620	4.65	0.0017
GC*PP*Cv	6	480.25	80.042	8.74	0.0000
Error Rep*GC*PP*Cv	32	293.02	9.157		
Total	71	3196.29			

Appendix 4.11: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	2.55	1.277		
Growing condition (GC)	1	33.94	33.935	5.44	0.1449
Error Rep*GC	2	12.47	6.237		
Planting period (PP)	3	1665.80	555.267	20.90	0.0000
GC*PP	3	195.18	65.061	2.45	0.1139
Error Rep*GC*PP	12	318.75	26.562		
Cultivar (Cv)	2	333.10	166.550	10.39	0.0003
GC*Cv	2	60.91	30.455	1.90	0.1661
PP*Cv	6	336.76	56.127	3.50	0.0089
GC*PP*Cv	6	198.94	33.156	2.07	0.0850
Error Rep*GC*PP*Cv	32	513.03	16.032		
Total	71	3671.43			

Appendix 4.12: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	5.34	2.670		
Growing condition (GC)	1	412.37	412.371	12.59	0.0711
Error Rep*GC	2	65.51	32.755		
Planting period (PP)	3	1332.11	444.037	24.86	0.0000
GC*PP	3	1570.25	523.418	29.30	0.0000
Error Rep*GC*PP	12	214.37	17.864		
Cultivar (Cv)	2	301.00	150.499	3.32	0.0488
GC*Cv	2	93.42	46.708	1.03	0.3680
PP*Cv	6	369.65	61.608	1.36	0.2602
GC*PP*Cv	6	485.14	80.857	1.79	0.1336
Error Rep*GC*PP*Cv	32	1448.83	45.276		
Total	71	6298.00			

Appendix 4.13: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	56.81	28.403		
Growing condition (GC)	1	103.61	103.608	29.32	0.0325
Error Rep*GC	2	7.07	3.534		
Planting period (PP)	3	1826.47	608.822	20.60	0.0001
GC*PP	3	1051.80	350.599	11.86	0.0007
Error Rep*GC*PP	12	354.61	29.551		
Cultivar (Cv)	2	138.43	69.214	2.52	0.0967
GC*Cv	2	107.88	53.939	1.96	0.1574
PP*Cv	6	543.90	90.650	3.29	0.0123
GC*PP*Cv	6	234.91	39.152	1.42	0.2366
Error Rep*GC*PP*Cv	32	880.61	27.519		
Total	71	5306.08			

Appendix 4.14: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	1.35	0.674		
Growing condition (GC)	1	24.65	24.652	277.80	0.0036
Error Rep*GC	2	0.18	0.089		
Planting period (PP)	3	295.11	98.369	15.61	0.0002
GC*PP	3	316.27	105.423	16.72	0.0001
Error Rep*GC*PP	12	75.64	6.304		
Cultivar (Cv)	2	156.28	78.141	8.50	0.0011
GC*Cv	2	61.31	30.655	3.34	0.0483
PP*Cv	6	240.76	40.126	4.37	0.0025
GC*PP*Cv	6	40.22	6.704	0.73	0.6293
Error Rep*GC*PP*Cv	32	294.07	9.190		
Total	71	1505.84			

Appendix 4.15: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	98.43	49.216		
Growing condition (GC)	1	0.18	0.177	0.01	0.9297
Error Rep*GC	2	35.61	17.806		
Planting period (PP)	3	365.33	121.775	3.51	0.0492
GC*PP	3	430.58	143.527	4.14	0.0314
Error Rep*GC*PP	12	416.14	34.678		
Cultivar (Cv)	2	73.60	36.801	2.38	0.1084
GC*Cv	2	84.09	42.047	2.72	0.0809
PP*Cv	6	284.60	47.434	3.07	0.0173
GC*PP*Cv	6	199.31	33.218	2.15	0.0743
Error Rep*GC*PP*Cv	32	494.01	15.438		
Total	71	2481.89			

Appendix 4.16: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on leaf area (cm^2) of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	14.69	7.345		
Growing condition (GC)	1	392.19	392.187	100.30	0.0098
Error Rep*GC	2	7.82	3.910		
Planting period (PP)	3	5.49	1.829	0.22	0.8788
GC*PP	3	173.03	57.678	7.02	0.0056
Error Rep*GC*PP	12	98.56	8.213		
Cultivar (Cv)	2	45.41	22.706	5.52	0.0087
GC*Cv	2	22.59	11.297	2.74	0.0794
PP*Cv	6	189.99	31.665	7.69	0.0000
GC*PP*Cv	6	40.95	6.826	1.66	0.1637
Error Rep*GC*PP*Cv	32	131.74	4.117		
Total	71	1122.46			

Appendix 4.17: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	5.028	2.514		
Growing condition (GC)	1	86.681	86.681	28.76	0.0331
Error Rep*GC	2	6.028	3.014		
Planting period (PP)	3	328.597	109.532	60.20	0.0000
GC*PP	3	20.486	6.829	3.75	0.0412
Error Rep*GC*PP	12	21.833	1.819		
Cultivar (Cv)	2	26.028	13.014	6.53	0.0042
GC*Cv	2	0.194	0.097	0.05	0.9525
PP*Cv	6	43.528	7.255	3.64	0.0072
GC*PP*Cv	6	10.472	1.745	0.88	0.5236
Error Rep*GC*PP*Cv	32	63.778	1.993		
Total	71	612.653			

Appendix 4.18: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	2.028	1.014		
Growing condition (GC)	1	346.722	346.722	82.94	0.0118
Error Rep*GC	2	8.361	4.181		
Planting period (PP)	3	371.167	123.722	58.48	0.0000
GC*PP	3	14.278	4.759	2.25	0.1350
Error Rep*GC*PP	12	25.389	2.116		
Cultivar (Cv)	2	33.444	16.722	9.63	0.0005
GC*Cv	2	3.111	1.556	0.90	0.4182
PP*Cv	6	54.000	9.000	5.18	0.0008
GC*PP*Cv	6	11.222	1.870	1.08	0.3966
Error Rep*GC*PP*Cv	32	55.556	1.736		
Total	71	925.278			

Appendix 4.19: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	0.69	0.347		
Growing condition (GC)	1	709.39	709.389	163.18	0.0061
Error Rep*GC	2	8.69	4.347		
Planting period (PP)	3	465.06	155.019	38.98	0.0000
GC*PP	3	73.06	24.352	6.12	0.0091
Error Rep*GC*PP	12	47.72	3.977		
Cultivar (Cv)	2	13.03	6.514	2.66	0.0850
GC*Cv	2	11.19	5.597	2.29	0.1176
PP*Cv	6	37.86	6.310	2.58	0.0374
GC*PP*Cv	6	24.36	4.060	1.66	0.1629
Error Rep*GC*PP*Cv	32	78.22	2.444		
Total	71	1469.28			

Appendix 4.20: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	3.69	1.85		
Growing condition (GC)	1	1449.01	1449.01	315.19	0.0032
Error Rep*GC	2	9.19	4.60		
Planting period (PP)	3	638.49	212.83	72.74	0.0000
GC*PP	3	213.82	71.27	24.36	0.0000
Error Rep*GC*PP	12	35.11	2.93		
Cultivar (Cv)	2	2.53	1.26	0.41	0.6653
GC*Cv	2	9.19	4.60	1.50	0.2382
PP*Cv	6	21.47	3.58	1.17	0.3474
GC*PP*Cv	6	9.47	1.58	0.52	0.7921
Error Rep*GC*PP*Cv	32	98.00	3.06		
Total	71	2489.99			

Appendix 4.21: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	3.11	1.56		
Growing condition (GC)	1	2323.35	2323.35	685.58	0.0015
Error Rep*GC	2	6.78	3.39		
Planting period (PP)	3	839.60	279.87	78.10	0.0000
GC*PP	3	347.15	115.72	32.29	0.0000
Error Rep*GC*PP	12	43.00	3.58		
Cultivar (Cv)	2	1.03	0.51	0.18	0.8357
GC*Cv	2	15.36	7.68	2.70	0.0827
PP*Cv	6	22.19	3.70	1.30	0.2858
GC*PP*Cv	6	10.31	1.72	0.60	0.7256
Error Rep*GC*PP*Cv	32	91.11	2.85		
Total	71	3702.99			

Appendix 4.22: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of branches of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	4.08	2.04		
Growing condition (GC)	1	2415.13	2415.13	1016.89	0.0010
Error Rep*GC	2	4.75	2.38		
Planting period (PP)	3	922.15	307.38	80.87	0.0000
GC*PP	3	393.15	131.05	34.48	0.0000
Error Rep*GC*PP	12	45.61	3.80		
Cultivar (Cv)	2	0.33	0.17	0.05	0.9492
GC*Cv	2	14.33	7.17	2.24	0.1225
PP*Cv	6	20.56	3.43	1.07	0.3993
GC*PP*Cv	6	10.56	1.76	0.55	0.7657
Error Rep*GC*PP*Cv	32	102.22	3.19		
Total	71	3932.88			

Appendix 4.23: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	859	430		
Growing condition (GC)	1	198240	198240	388.82	0.0026
Error Rep*GC	2	1020	510		
Planting period (PP)	3	46675	15558	162.08	0.0000
GC*PP	3	31896	10632	110.76	0.0000
Error Rep*GC*PP	12	1152	96		
Cultivar (Cv)	2	763	382	2.61	0.0893
GC*Cv	2	360	180	1.23	0.3052
PP*Cv	6	3560	593	4.06	0.0039
GC*PP*Cv	6	2709	451	3.09	0.0169
Error Rep*GC*PP*Cv	32	4681	146		
Total	71	291916			

Appendix 4.24: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	475	237		
Growing condition (GC)	1	350424	350424	1466.89	0.0007
Error Rep*GC	2	478	239		
Planting period (PP)	3	72290	24097	254.96	0.0000
GC*PP	3	55489	18496	195.71	0.0000
Error Rep*GC*PP	12	1134	95		
Cultivar (Cv)	2	652	326	4.72	0.0160
GC*Cv	2	162	81	1.17	0.3223
PP*Cv	6	2575	429	6.22	0.0002
GC*PP*Cv	6	1761	294	4.25	0.0029
Error Rep*GC*PP*Cv	32	2209	69		
Total	71	487649			

Appendix 4.25: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	564	282		
Growing condition (GC)	1	512916	512916	1541.38	0.0006
Error Rep*GC	2	666	333		
Planting period (PP)	3	108510	36170	265.54	0.0000
GC*PP	3	92113	30704	225.42	0.0000
Error Rep*GC*PP	12	1635	136		
Cultivar (Cv)	2	108	54	0.40	0.6734
GC*Cv	2	15	8	0.06	0.9451
PP*Cv	6	2095	349	2.60	0.0363
GC*PP*Cv	6	1785	297	2.22	0.0671
Error Rep*GC*PP*Cv	32	4297	134		
Total	71	724702			

Appendix 4.26: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	53	26		
Growing condition (GC)	1	546535	546535	6914.52	0.0001
Error Rep*GC	2	158	79		
Planting period (PP)	3	92229	30743	224.89	0.0000
GC*PP	3	81203	27068	198.00	0.0000
Error Rep*GC*PP	12	1640	137		
Cultivar (Cv)	2	95	48	0.32	0.7284
GC*Cv	2	46	23	0.15	0.8572
PP*Cv	6	1807	301	2.02	0.0913
GC*PP*Cv	6	1076	179	1.21	0.3288
Error Rep*GC*PP*Cv	32	4762	149		
Total	71	729605			

Appendix 4.27: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	44	22		
Growing condition (GC)	1	529592	529592	15608.12	0.0001
Error Rep*GC	2	68	34		
Planting period (PP)	3	130736	43579	332.57	0.0000
GC*PP	3	115825	38608	294.64	0.0000
Error Rep*GC*PP	12	1572	131		
Cultivar (Cv)	2	23	11	0.08	0.9263
GC*Cv	2	48	24	0.16	0.8498
PP*Cv	6	2461	410	2.79	0.0267
GC*PP*Cv	6	1961	327	2.23	0.0659
Error Rep*GC*PP*Cv	32	4696	147		
Total	71	787026			

Appendix 4.28: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of leaves of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	50	25.2		
Growing condition (GC)	1	91093	91093.3	13467.60	0.0001
Error Rep*GC	2	14	6.8		
Planting period (PP)	3	37340	12446.6	87.27	0.0000
GC*PP	3	20868	6956.1	48.77	0.0000
Error Rep*GC*PP	12	1711	142.6		
Cultivar (Cv)	2	5	2.4	0.04	0.9596
GC*Cv	2	54	26.9	0.46	0.6324
PP*Cv	6	1688	281.4	4.87	0.0012
GC*PP*Cv	6	1614	269.1	4.65	0.0017
Error Rep*GC*PP*Cv	32	1851	57.8		
Total	71	156289			

Appendix 4.29: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	132.2	66.11		
Growing condition (GC)	1	8551.1	8551.05	27.24	0.0348
Error Rep*GC	2	627.7	313.87		
Planting period (PP)	3	4686.3	1562.10	16.28	0.0002
GC*PP	3	4488.0	1495.99	15.59	0.0002
Error Rep*GC*PP	12	1151.7	95.97		
Cultivar (Cv)	2	960.7	480.35	8.38	0.0012
GC*Cv	2	405.9	202.93	3.54	0.0408
PP*Cv	6	478.8	79.80	1.39	0.2478
GC*PP*Cv	6	232.9	38.82	0.68	0.6687
Error Rep*GC*PP*Cv	32	1833.7	57.30		
Total	71	23548.9			

Appendix 4.30: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	79.8	39.9		
Growing condition (GC)	1	13773.9	13773.9	57.14	0.0171
Error Rep*GC	2	482.1	241.0		
Planting period (PP)	3	12248.7	4082.9	30.10	0.0000
GC*PP	3	6929.7	2309.9	17.03	0.0001
Error Rep*GC*PP	12	1627.6	135.6		
Cultivar (Cv)	2	1475.4	737.7	9.00	0.0008
GC*Cv	2	730.0	365.0	4.45	0.0197
PP*Cv	6	716.3	119.4	1.46	0.2247
GC*PP*Cv	6	365.3	60.9	0.74	0.6197
Error Rep*GC*PP*Cv	32	2624.2	82.0		
Total	71	41052.7			

Appendix 4.31: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	165.7	82.8		
Growing condition (GC)	1	17870.9	17870.9	100.62	0.0098
Error Rep*GC	2	355.2	177.6		
Planting period (PP)	3	16492.5	5497.5	38.11	0.0000
GC*PP	3	9786.4	3262.1	22.62	0.0000
Error Rep*GC*PP	12	1730.9	144.2		
Cultivar (Cv)	2	1545.3	772.7	9.18	0.0007
GC*Cv	2	643.1	321.5	3.82	0.0326
PP*Cv	6	721.7	120.3	1.43	0.2344
GC*PP*Cv	6	317.6	52.9	0.63	0.7062
Error Rep*GC*PP*Cv	32	2694.4	84.2		
Total	71	52323.6			

Appendix 4.32: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	133.9	66.9		
Growing condition (GC)	1	21081.6	21081.6	119.56	0.0083
Error Rep*GC	2	352.6	176.3		
Planting period (PP)	3	19073.0	6357.7	44.16	0.0000
GC*PP	3	8466.1	2822.0	19.60	0.0001
Error Rep*GC*PP	12	1727.5	144.0		
Cultivar (Cv)	2	1593.2	796.6	10.42	0.0003
GC*Cv	2	586.1	293.0	3.83	0.0322
PP*Cv	6	840.3	140.0	1.83	0.1241
GC*PP*Cv	6	354.0	59.0	0.77	0.5978
Error Rep*GC*PP*Cv	32	2446.1	76.4		
Total	71	56654.3			

Appendix 4.33: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	133.9	67.0		
Growing condition (GC)	1	23707.2	23707.2	115.30	0.0086
Error Rep*GC	2	411.2	205.6		
Planting period (PP)	3	22471.8	7490.6	49.37	0.0000
GC*PP	3	7778.9	2593.0	17.09	0.0001
Error Rep*GC*PP	12	1820.8	151.7		
Cultivar (Cv)	2	1198.1	599.0	8.04	0.0015
GC*Cv	2	292.1	146.1	1.96	0.1575
PP*Cv	6	704.8	117.5	1.58	0.1863
GC*PP*Cv	6	502.7	83.8	1.12	0.3707
Error Rep*GC*PP*Cv	32	2385.4	74.5		
Total	71	61406.9			

Appendix 4.34: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on plant height (cm) of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	103.8	51.9		
Growing condition (GC)	1	24366.0	24366.0	119.36	0.0083
Error Rep*GC	2	408.3	204.1		
Planting period (PP)	3	22582.4	7527.5	49.53	0.0000
GC*PP	3	8099.0	2699.7	17.76	0.0001
Error Rep*GC*PP	12	1823.6	152.0		
Cultivar (Cv)	2	1193.9	597.0	7.87	0.0017
GC*Cv	2	245.2	122.6	1.62	0.2145
PP*Cv	6	726.3	121.1	1.60	0.1806
GC*PP*Cv	6	482.0	80.3	1.06	0.4072
Error Rep*GC*PP*Cv	32	2427.7	75.9		
Total	71	62458.3			

Appendix 4.35: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	1.713	0.8567		
Growing condition (GC)	1	97.650	97.6503	111.28	0.0089
Error Rep*GC	2	1.755	0.8775		
Planting period (PP)	3	157.550	52.5167	80.51	0.0000
GC*PP	3	54.150	18.0499	27.67	0.0000
Error Rep*GC*PP	12	7.828	0.6523		
Cultivar (Cv)	2	26.475	13.2377	16.18	0.0000
GC*Cv	2	41.433	20.7164	25.32	0.0000
PP*Cv	6	142.110	23.6850	28.94	0.0000
GC*PP*Cv	6	126.768	21.1280	25.82	0.0000
Error Rep*GC*PP*Cv	32	26.185	0.8183		
Total	71	683.618			

Appendix 4.36: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 8 WAT

Source	DF	SS	MS	F	P
Rep	2	1.14	0.571		
Growing condition (GC)	1	253.43	253.425	311.97	0.0032
Error Rep*GC	2	1.62	0.812		
Planting period (PP)	3	271.78	90.594	134.42	0.0000
GC*PP	3	137.76	45.919	68.14	0.0000
Error Rep*GC*PP	12	8.09	0.674		
Cultivar (Cv)	2	42.44	21.221	27.75	0.0000
GC*Cv	2	89.79	44.896	58.71	0.0000
PP*Cv	6	263.45	43.909	57.42	0.0000
GC*PP*Cv	6	238.79	39.799	52.04	0.0000
Error Rep*GC*PP*Cv	32	24.47	0.765		
Total	71	1332.77			

Appendix 4.37: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 10 WAT

Source	DF	SS	MS	F	P
Rep	2	0.20	0.101		
Growing condition (GC)	1	436.65	436.651	429.91	0.0023
Error Rep*GC	2	2.03	1.016		
Planting period (PP)	3	321.18	107.061	151.39	0.0000
GC*PP	3	197.91	65.969	93.28	0.0000
Error Rep*GC*PP	12	8.49	0.707		
Cultivar (Cv)	2	82.53	41.267	47.19	0.0000
GC*Cv	2	136.05	68.024	77.78	0.0000
PP*Cv	6	393.85	65.641	75.06	0.0000
GC*PP*Cv	6	372.96	62.160	71.08	0.0000
Error Rep*GC*PP*Cv	32	27.99	0.875		
Total	71	1979.83			

Appendix 4.38: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 12 WAT

Source	DF	SS	MS	F	P
Rep	2	0.37	0.186		
Growing condition (GC)	1	766.17	766.166	1278.03	0.0008
Error Rep*GC	2	1.20	0.599		
Planting period (PP)	3	435.01	145.005	234.85	0.0000
GC*PP	3	309.23	103.077	166.94	0.0000
Error Rep*GC*PP	12	7.41	0.617		
Cultivar (Cv)	2	140.38	70.190	70.98	0.0000
GC*Cv	2	187.70	93.851	94.91	0.0000
PP*Cv	6	495.60	82.600	83.53	0.0000
GC*PP*Cv	6	462.57	77.096	77.97	0.0000
Error Rep*GC*PP*Cv	32	31.64	0.989		
Total	71	2837.29			

Appendix 4.39: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 14 WAT

Source	DF	SS	MS	F	P
Rep	2	0.21	0.11		
Growing condition (GC)	1	1103.33	1103.33	1767.72	0.0006
Error Rep*GC	2	1.25	0.62		
Planting period (PP)	3	527.22	175.74	224.17	0.0000
GC*PP	3	389.42	129.81	165.58	0.0000
Error Rep*GC*PP	12	9.41	0.78		
Cultivar (Cv)	2	193.61	96.81	98.70	0.0000
GC*Cv	2	243.35	121.67	124.06	0.0000
PP*Cv	6	627.70	104.62	106.67	0.0000
GC*PP*Cv	6	592.98	98.83	100.77	0.0000
Error Rep*GC*PP*Cv	32	31.38	0.98		
Total	71	3719.86			

Appendix 4.40: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on stem diameter (mm) of *Corchorus olitorius* at 16 WAT

Source	DF	SS	MS	F	P
Rep	2	0.45	0.23		
Growing condition (GC)	1	1168.30	1168.30	2518.39	0.0004
Error Rep*GC	2	0.93	0.46		
Planting period (PP)	3	569.18	189.73	211.78	0.0000
GC*PP	3	430.23	143.41	160.08	0.0000
Error Rep*GC*PP	12	10.75	0.90		
Cultivar (Cv)	2	204.66	102.33	94.15	0.0000
GC*Cv	2	254.31	127.16	116.99	0.0000
PP*Cv	6	654.84	109.14	100.42	0.0000
GC*PP*Cv	6	620.01	103.33	95.07	0.0000
Error Rep*GC*PP*Cv	32	34.78	1.09		
Total	71	3948.43			

Appendix 4.41: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on dry root mass (g) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	12.831	6.415		
Growing condition (GC)	1	309.424	309.424	38.88	0.0248
Error Rep*GC	2	15.917	7.958		
Planting period (PP)	3	104.496	34.832	18.42	0.0001
GC*PP	3	73.710	24.570	13.00	0.0004
Error Rep*GC*PP	12	22.688	1.891		
Cultivar (Cv)	2	11.411	5.706	13.11	0.0001
GC*Cv	2	7.047	3.523	8.09	0.0014
PP*Cv	6	4.990	0.832	1.91	0.1094
GC*PP*Cv	6	5.575	0.929	2.13	0.0764
Error Rep*GC*PP*Cv	32	13.929	0.435		
Total	71	582.018			

Appendix 4.42: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on dry shoot mass (g) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	252.3	126.15		
Growing condition (GC)	1	6869.1	6869.09	44.42	0.0218
Error Rep*GC	2	309.3	154.64		
Planting period (PP)	3	2470.1	823.38	30.65	0.0000
GC*PP	3	2568.3	856.12	31.87	0.0000
Error Rep*GC*PP	12	322.4	26.86		
Cultivar (Cv)	2	53.7	26.87	1.18	0.3213
GC*Cv	2	66.7	33.33	1.46	0.2474
PP*Cv	6	40.7	6.78	0.30	0.9340
GC*PP*Cv	6	17.3	2.89	0.13	0.9922
Error Rep*GC*PP*Cv	32	730.7	22.83		
Total	71	13700.6			

Appendix 4.43: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on fresh root mass (g) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	485.9	242.9		
Growing condition (GC)	1	15236.8	15236.8	57.93	0.0168
Error Rep*GC	2	526.1	263.0		
Planting period (PP)	3	17074.5	5691.5	62.91	0.0000
GC*PP	3	14831.0	4943.7	54.65	0.0000
Error Rep*GC*PP	12	1085.6	90.5		
Cultivar (Cv)	2	206.4	103.2	3.81	0.0327
GC*Cv	2	205.7	102.8	3.80	0.0330
PP*Cv	6	399.4	66.6	2.46	0.0453
GC*PP*Cv	6	475.6	79.3	2.93	0.0216
Error Rep*GC*PP*Cv	32	865.7	27.1		
Total	71	51392.5			

Appendix 4.44: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on fresh shoot mass (g) of *Corchorus olitorius* at 6 WAT

Source	DF	SS	MS	F	P
Rep	2	3111	1556		
Growing condition (GC)	1	110832	110832	48.98	0.0198
Error Rep*GC	2	4526	2263		
Planting period (PP)	3	82034	27345	77.67	0.0000
GC*PP	3	94333	31444	89.32	0.0000
Error Rep*GC*PP	12	4225	352		
Cultivar (Cv)	2	308	154	0.29	0.7509
GC*Cv	2	468	234	0.44	0.6482
PP*Cv	6	354	59	0.11	0.9945
GC*PP*Cv	6	105	18	0.03	0.9998
Error Rep*GC*PP*Cv	32	17031	532		
Total	71	317326			

Appendix 4.45: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on dry root mass (g) of *Corchorus olitorius* at 18 WAT

Source	DF	SS	MS	F	P
Rep	2	55.4	27.69		
Growing condition (GC)	1	7073.2	7073.16	168.27	0.0059
Error Rep*GC	2	84.1	42.04		
Planting period (PP)	3	4258.4	1419.45	41.34	0.0000
GC*PP	3	2659.0	886.34	25.82	0.0000
Error Rep*GC*PP	12	412.0	34.33		
Cultivar (Cv)	2	300.9	150.44	3.78	0.0337
GC*Cv	2	133.3	66.64	1.67	0.2037
PP*Cv	6	368.8	61.47	1.54	0.1961
GC*PP*Cv	6	569.8	94.96	2.38	0.0612
Error Rep*GC*PP*Cv	32	1274.6	39.83		
Total	71	17189.4			

Appendix 4.46: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on dry shoot mass (g) of *Corchorus olitorius* at 18 WAT

Source	DF	SS	MS	F	P
Rep	2	1951	975		
Growing condition (GC)	1	239004	239004	729.54	0.0014
Error Rep*GC	2	655	328		
Planting period (PP)	3	94888	31629	35.05	0.0000
GC*PP	3	58295	19432	21.53	0.0000
Error Rep*GC*PP	12	10829	902		
Cultivar (Cv)	2	1970	985	0.73	0.4920
GC*Cv	2	2084	1042	0.77	0.4729
PP*Cv	6	7885	1314	0.97	0.4628
GC*PP*Cv	6	7672	1279	0.94	0.4797
Error Rep*GC*PP*Cv	32	43478	1359		
Total	71	468711			

Appendix 4.47: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on fresh root mass (g) of *Corchorus olitorius* at 18 WAT

Source	DF	SS	MS	F	P
Rep	2	18.7	9.37		
Growing condition (GC)	1	7889.8	7889.77	689.74	0.0014
Error Rep*GC	2	22.9	11.44		
Planting period (PP)	3	4649.3	1549.76	25.83	0.0000
GC*PP	3	2813.1	937.69	15.63	0.0002
Error Rep*GC*PP	12	719.9	59.99		
Cultivar (Cv)	2	93.6	46.79	1.09	0.3486
GC*Cv	2	0.7	0.37	0.01	0.9914
PP*Cv	6	401.6	66.93	1.56	0.1915
GC*PP*Cv	6	752.5	125.42	2.92	0.0219
Error Rep*GC*PP*Cv	32	1374.3	42.95		
Total	71	18736.4			

Appendix 4.48: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on fresh shoot mass (g) of *Corchorus olitorius* at 18 WAT

Source	DF	SS	MS	F	P
Rep	2	181	91		
Growing condition (GC)	1	250487	250487	545.75	0.0018
Error Rep*GC	2	918	459		
Planting period (PP)	3	101137	33712	25.82	0.0000
GC*PP	3	60572	20191	15.47	0.0002
Error Rep*GC*PP	12	15666	1306		
Cultivar (Cv)	2	132	66	0.04	0.9561
GC*Cv	2	1684	842	0.57	0.5694
PP*Cv	6	5749	958	0.65	0.6881
GC*PP*Cv	6	7188	1198	0.82	0.5660
Error Rep*GC*PP*Cv	32	47014	1469		
Total	71	490729			

Appendix 4.49: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of days to flowering of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	108.00	54.00		
Growing condition (GC)	1	2640.22	2640.22	46.27	0.0209
Error Rep*GC	2	114.11	57.06		
Planting period (PP)	3	2847.44	949.15	43.34	0.0000
GC*PP	3	774.11	258.04	11.78	0.0007
Error Rep*GC*PP	12	262.78	21.90		
Cultivar (Cv)	2	852.08	426.04	21.88	0.0000
GC*Cv	2	2.53	1.26	0.06	0.9373
PP*Cv	6	181.14	30.19	1.55	0.1939
GC*PP*Cv	6	206.47	34.41	1.77	0.1376
Error Rep*GC*PP*Cv	32	623.11	19.47		
Total	71	8612.00			

Appendix 4.50: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of days to 50% flowering of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	39.5	19.76		
Growing condition (GC)	1	490.9	490.89	9.61	0.0902
Error Rep*GC	2	102.2	51.10		
Planting period (PP)	3	7454.8	2484.93	85.95	0.0000
GC*PP	3	338.1	112.70	3.90	0.0372
Error Rep*GC*PP	12	346.9	28.91		
Cultivar (Cv)	2	1202.1	601.06	93.98	0.0000
GC*Cv	2	1.8	0.89	0.14	0.8708
PP*Cv	6	159.9	26.65	4.17	0.0033
GC*PP*Cv	6	141.6	23.59	3.69	0.0067
Error Rep*GC*PP*Cv	32	204.7	6.40		
Total	71	10482.4			

Appendix 4.51: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of days to 50% pod formation of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	33.4	16.68		
Growing condition (GC)	1	280.1	280.06	2.37	0.2632
Error Rep*GC	2	235.9	117.93		
Planting period (PP)	3	8810.6	2936.85	60.77	0.0000
GC*PP	3	253.4	84.46	1.75	0.2105
Error Rep*GC*PP	12	579.9	48.32		
Cultivar (Cv)	2	1510.1	755.06	82.87	0.0000
GC*Cv	2	1.8	0.89	0.10	0.9073
PP*Cv	6	170.4	28.41	3.12	0.0161
GC*PP*Cv	6	231.4	38.57	4.23	0.0030
Error Rep*GC*PP*Cv	32	291.6	9.11		
Total	71	12398.4			

Appendix 4.52: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of days to 50% pod maturity of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	71.4	35.68		
Growing condition (GC)	1	3226.7	3226.72	19.88	0.0468
Error Rep*GC	2	324.7	162.35		
Planting period (PP)	3	9514.8	3171.59	45.53	0.0000
GC*PP	3	238.9	79.65	1.14	0.3712
Error Rep*GC*PP	12	835.9	69.66		
Cultivar (Cv)	2	1732.7	866.35	71.82	0.0000
GC*Cv	2	12.2	6.10	0.51	0.6080
PP*Cv	6	259.0	43.16	3.58	0.0079
GC*PP*Cv	6	326.8	54.47	4.52	0.0020
Error Rep*GC*PP*Cv	32	386.0	12.06		
Total	71	16929.1			

Appendix 4.53: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on number of pods of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	763.2	381.6		
Growing condition (GC)	1	27808.7	27808.7	133.47	0.0074
Error Rep*GC	2	416.7	208.3		
Planting period (PP)	3	12023.5	4007.8	16.90	0.0001
GC*PP	3	1088.0	362.7	1.53	0.2575
Error Rep*GC*PP	12	2846.6	237.2		
Cultivar (Cv)	2	2071.0	1035.5	4.33	0.0217
GC*Cv	2	479.2	239.6	1.00	0.3785
PP*Cv	6	1289.3	214.9	0.90	0.5080
GC*PP*Cv	6	582.9	97.2	0.41	0.8694
Error Rep*GC*PP*Cv	32	7653.6	239.2		
Total	71	57022.7			

Appendix 4.54: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on pod weight (g) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	2020	1009.8		
Growing condition (GC)	1	6935	6935.5	47.72	0.0203
Error Rep*GC	2	291	145.3		
Planting period (PP)	3	62147	20715.6	194.70	0.0000
GC*PP	3	14637	4879.0	45.86	0.0000
Error Rep*GC*PP	12	1277	106.4		
Cultivar (Cv)	2	1634	817.2	2.48	0.0993
GC*Cv	2	277	138.7	0.42	0.6596
PP*Cv	6	1516	252.7	0.77	0.6004
GC*PP*Cv	6	448	74.7	0.23	0.9648
Error Rep*GC*PP*Cv	32	10526	329.0		
Total	71	101709			

Appendix 4.55: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on seed yield (g) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	5.405	2.7025		
Growing condition (GC)	1	2.936	2.9363	4.45	0.1695
Error Rep*GC	2	1.321	0.6604		
Planting period (PP)	3	38.648	12.8827	46.58	0.0000
GC*PP	3	15.987	5.3292	19.27	0.0001
Error Rep*GC*PP	12	3.319	0.2766		
Cultivar (Cv)	2	5.737	2.8683	4.34	0.0216
GC*Cv	2	0.623	0.3113	0.47	0.6288
PP*Cv	6	5.606	0.9344	1.41	0.2403
GC*PP*Cv	6	0.913	0.1522	0.23	0.9638
Error Rep*GC*PP*Cv	32	21.167	0.6615		
Total	71	101.662			

Appendix 4.56: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of copper (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	3.634	1.8168		
Growing condition (GC)	1	0.823	0.8235	0.98	0.4261
Error Rep*GC	2	1.677	0.8385		
Planting period (PP)	3	101.125	33.7083	20.85	0.0000
GC*PP	3	6.109	2.0364	1.26	0.3321
Error Rep*GC*PP	12	19.405	1.6171		
Cultivar (Cv)	2	44.548	22.2739	18.56	0.0000
GC*Cv	2	3.414	1.7072	1.42	0.2559
PP*Cv	6	3.809	0.6348	0.53	0.7820
GC*PP*Cv	6	10.298	1.7163	1.43	0.2338
Error Rep*GC*PP*Cv	32	38.398	1.1999		
Total	71	233.240			

Appendix 4.57: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Manganese (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	128.58	64.292		
Growing condition (GC)	1	6.13	6.125	0.53	0.5421
Error Rep*GC	2	23.08	11.542		
Planting period (PP)	3	860.71	286.903	4.37	0.0268
GC*PP	3	121.60	40.532	0.62	0.6170
Error Rep*GC*PP	12	788.11	65.676		
Cultivar (Cv)	2	405.33	202.667	6.54	0.0042
GC*Cv	2	61.00	30.500	0.98	0.3847
PP*Cv	6	446.67	74.444	2.40	0.0497
GC*PP*Cv	6	86.11	14.352	0.46	0.8302
Error Rep*GC*PP*Cv	32	991.56	30.986		
Total	71	3918.87			

Appendix 4.58: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Iron (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	80520.8	40260		
Growing condition (GC)	1	11883.7	11884	0.09	0.7918
Error Rep*GC	2	262282	131141		
Planting period (PP)	3	1.265E+07	4218276	39.15	0.0000
GC*PP	3	73580.7	24527	0.23	0.8754
Error Rep*GC*PP	12	1292977	107748		
Cultivar (Cv)	2	309957	154979	2.09	0.1398
GC*Cv	2	21613.0	10807	0.15	0.8647
PP*Cv	6	500657	83443	1.13	0.3689
GC*PP*Cv	6	43849.1	7308	0.10	0.9960
Error Rep*GC*PP*Cv	32	2368368	74011		
Total	71	1.762E+07			

Appendix 4.59: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Phosphorus (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	0.00102	0.00051		
Growing condition (GC)	1	0.00007	0.00007	0.08	0.8030
Error Rep*GC	2	0.00169	0.00084		
Planting period (PP)	3	0.04024	0.01341	3.46	0.0513
GC*PP	3	0.04153	0.01384	3.57	0.0472
Error Rep*GC*PP	12	0.04656	0.00388		
Cultivar (Cv)	2	0.02269	0.01134	5.29	0.0104
GC*Cv	2	0.00154	0.00077	0.36	0.7019
PP*Cv	6	0.01973	0.00329	1.53	0.1996
GC*PP*Cv	6	0.00525	0.00088	0.41	0.8682
Error Rep*GC*PP*Cv	32	0.06867	0.00215		
Total	71	0.24897			

Appendix 4.60: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Aluminium (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	46447.7	23224		
Growing condition (GC)	1	20234.0	20234	0.21	0.6944
Error Rep*GC	2	196428	98214		
Planting period (PP)	3	1.330E+07	4434365	48.27	0.0000
GC*PP	3	131357	43786	0.48	0.7044
Error Rep*GC*PP	12	1102325	91860		
Cultivar (Cv)	2	421047	210523	3.24	0.0523
GC*Cv	2	7523.86	3762	0.06	0.9438
PP*Cv	6	488718	81453	1.25	0.3061
GC*PP*Cv	6	26845.9	4474	0.07	0.9985
Error Rep*GC*PP*Cv	32	2079096	64972		
Total	71	1.782E+07			

Appendix 4.61: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Nitrogen (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	0.0347	0.01734		
Growing condition (GC)	1	0.4156	0.41557	15.15	0.0601
Error Rep*GC	2	0.0549	0.02743		
Planting period (PP)	3	22.8984	7.63280	96.96	0.0000
GC*PP	3	0.3122	0.10408	1.32	0.3129
Error Rep*GC*PP	12	0.9447	0.07872		
Cultivar (Cv)	2	3.1926	1.59628	25.54	0.0000
GC*Cv	2	0.0847	0.04234	0.68	0.5150
PP*Cv	6	1.3984	0.23307	3.73	0.0063
GC*PP*Cv	6	0.2218	0.03697	0.59	0.7346
Error Rep*GC*PP*Cv	32	1.9998	0.06249		
Total	71	31.5576			

Appendix 4.62: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Calcium (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	0.11000	0.05500		
Growing condition (GC)	1	0.00222	0.00222	0.18	0.7146
Error Rep*GC	2	0.02507	0.01253		
Planting period (PP)	3	1.45748	0.48583	12.78	0.0005
GC*PP	3	0.12883	0.04294	1.13	0.3762
Error Rep*GC*PP	12	0.45631	0.03803		
Cultivar (Cv)	2	1.64339	0.82169	41.89	0.0000
GC*Cv	2	0.01002	0.00501	0.26	0.7762
PP*Cv	6	0.41031	0.06839	3.49	0.0091
GC*PP*Cv	6	0.21399	0.03567	1.82	0.1269
Error Rep*GC*PP*Cv	32	0.62776	0.01962		
Total	71	5.08538			

Appendix 4.63: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Magnesium (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	0.01734	0.00867		
Growing condition (GC)	1	0.00094	0.00094	8.89	0.0964
Error Rep*GC	2	0.00021	0.00011		
Planting period (PP)	3	0.16428	0.05476	34.54	0.0000
GC*PP	3	0.00165	0.00055	0.35	0.7920
Error Rep*GC*PP	12	0.01902	0.00159		
Cultivar (Cv)	2	0.00154	0.00077	0.50	0.6096
GC*Cv	2	0.00197	0.00098	0.64	0.5316
PP*Cv	6	0.03046	0.00508	3.32	0.0117
GC*PP*Cv	6	0.00308	0.00051	0.34	0.9131
Error Rep*GC*PP*Cv	32	0.04889	0.00153		
Total	71	0.28938			

Appendix 4.64: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Potassium (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	0.5812	0.29060		
Growing condition (GC)	1	0.0351	0.03511	0.34	0.6193
Error Rep*GC	2	0.2071	0.10355		
Planting period (PP)	3	17.5082	5.83608	17.55	0.0001
GC*PP	3	0.2097	0.06989	0.21	0.8874
Error Rep*GC*PP	12	3.9913	0.33261		
Cultivar (Cv)	2	0.8841	0.44205	4.65	0.0169
GC*Cv	2	0.0406	0.02028	0.21	0.8091
PP*Cv	6	2.7552	0.45920	4.83	0.0013
GC*PP*Cv	6	0.8601	0.14336	1.51	0.2073
Error Rep*GC*PP*Cv	32	3.0425	0.09508		
Total	71	30.1151			

Appendix 4.65: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Sodium (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	36075	18037.3		
Growing condition (GC)	1	2005	2004.5	0.27	0.6538
Error Rep*GC	2	14723	7361.5		
Planting period (PP)	3	59416	19805.5	1.48	0.2686
GC*PP	3	110666	36888.7	2.76	0.0879
Error Rep*GC*PP	12	160175	13347.9		
Cultivar (Cv)	2	32312	16156.2	1.57	0.2228
GC*Cv	2	29205	14602.3	1.42	0.2559
PP*Cv	6	101674	16945.7	1.65	0.1655
GC*PP*Cv	6	80587	13431.2	1.31	0.2818
Error Rep*GC*PP*Cv	32	328454	10264.2		
Total	71	955292			

Appendix 4.66: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on the amount of Zinc (mg/kg) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	3913.58	1956.79		
Growing condition (GC)	1	5.049E-29	5.049E-29	0.00	1.0000
Error Rep*GC	2	6.25000	3.12500		
Planting period (PP)	3	348.333	116.111	1.30	0.3206
GC*PP	3	41.6667	13.8889	0.16	0.9244
Error Rep*GC*PP	12	1074.83	89.5694		
Cultivar (Cv)	2	342.583	171.292	3.03	0.0626
GC*Cv	2	221.083	110.542	1.95	0.1584
PP*Cv	6	604.417	100.736	1.78	0.1349
GC*PP*Cv	6	923.917	153.986	2.72	0.0300
Error Rep*GC*PP*Cv	32	1811.33	56.6042		
Total	71	9288.00			

Appendix 4.67: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on ash (%) of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	22.99	11.493		
Growing condition (GC)	1	1.52	1.523	1.02	0.4196
Error Rep*GC	2	3.00	1.498		
Planting period (PP)	3	659.23	219.744	25.10	0.0000
GC*PP	3	15.94	5.314	0.61	0.6230
Error Rep*GC*PP	12	105.06	8.755		
Cultivar (Cv)	2	16.84	8.421	0.94	0.4009
GC*Cv	2	6.73	3.364	0.38	0.6897
PP*Cv	6	94.02	15.670	1.75	0.1413
GC*PP*Cv	6	25.51	4.251	0.47	0.8218
Error Rep*GC*PP*Cv	32	286.45	8.952		
Total	71	1237.28			

Appendix 4.68: Analysis of variance for the interactive effect of growing condition, planting period and cultivar on dry matter of *Corchorus olitorius*

Source	DF	SS	MS	F	P
Rep	2	5.536	2.76813		
Growing condition (GC)	1	0.016	0.01590	0.27	0.6527
Error Rep*GC	2	0.116	0.05798		
Planting period (PP)	3	11.978	3.99264	1.25	0.3338
GC*PP	3	8.157	2.71913	0.85	0.4910
Error Rep*GC*PP	12	38.203	3.18358		
Cultivar (Cv)	2	5.976	2.98805	1.35	0.2729
GC*Cv	2	4.754	2.37701	1.08	0.3530
PP*Cv	6	15.533	2.58876	1.17	0.3456
GC*PP*Cv	6	20.471	3.41178	1.54	0.1957
Error Rep*GC*PP*Cv	32	70.688	2.20900		
Total	71	181.428			