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YIELD AND ECONOMIC VIABILITY OF INTERCROPPING JUTE MALLOW (*CORCHORUS OLITORIUS*) WITH CEREALS IN SELECTED LOCATIONS OF TANZANIA

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A Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

Arusha, Tanzania

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ABSTRACT

This study was conducted to evaluate the yield and economic viability of intercropping Jute mallow with different cereal crop combinations so that farmers can maximize land use and crop resources for improved crop productivity, nutrition and income. Field experiments in a randomized complete block design (RCBD) with three replications were conducted at Dodoma and Arusha. Results indicated that growth parameters of Jute mallow (such as plant height, number of branches and number of leaves) were not affected (p=0.05) when intercropped with either Sorghum or Finger millet. Jute mallow intercropped with Maize suppressed growth and yield performance of Jute mallow, for instance in plant height from 73.69 cm to 44.59 cm and fresh leaf yield from 41.75 g to 30.48 g. Fresh leaf yield of sole Jute mallow (41.75 g) did not significantly (p=0.05) differ from Jute mallow with Sorghum (39.92 g) and Finger millet (37.89 g) intercrops at p=0.05. Yield performance of intercropped cereals decreased (p=0.05) with intercropping. Nutritional content was high (p=0.05) in intercropped Jute mallow combinations than its sole stand in crude protein, potassium, nitrogen and calcium but decreased vitamin C levels with intercropping. The highest Marginal Rate of Return of 4.76 and 4.69 was from Jute mallow intercropped with Maize and with Sorghum in Arusha and Dodoma respectively. Jute mallow-Sorghum intercrop had the highest Land Equivalent Ratio of 1.7 in Dodoma and 1.53 in Arusha. This study recommends Jute mallow as a viable intercrop with cereal especially Sorghum and Maize in Dodoma and Arusha respectively.

DECLARATION

I, Margareth A. Makauki declare to the Senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Student Signature: .... Date: 25/4/2020

Margareth A. Makauki

The above declaration is confirmed

Prof. Patrick A. Ndakidemi	....	05-05-2020
(Principal supervisor)	Signature	Date
Dr. Ernest R. Mbega	....	05-05-2020
(Co-supervisor)	Signature	Date
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(Co-supervisor)	Signature	Date

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CERTIFICATION

The undersigned certify that they have read the dissertation titled "Yield and Economic viability of Intercropping Jute Mallow (*Corchorus olitorius*) with Cereals in Selected Locations of Tanzania" and recommend for examination in fulfilment of the requirements for the degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology.

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Last but not least I am greatly thankful to my classmates and all individuals whose support, encouragement and assistance enabled me to complete this study.

DEDICATION

This piece of work is dedicated to the greatness of magnificent God.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
ANOVA	Analysis of Variance
ºC	Celsius degrees
cm	Centimeter
FAO	Food and Agricultural Organization
g	Gram
ha	Hectare
kg	Kilogram
LER	Land Equivalent Ratio
LSD	Least Significant Difference
m.a.s.l	Meter above sea level
mg	Milligram
NM-AIST	Nelson Mandela African Institution of Science and Technology
PGR	Plant Genetic Resource
TVC	Total Variable Cost
USD	United States Dollar

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

African indigenous leaf vegetables are important sources of household nutrition and are highly valued for their medicinal importance all over Africa (Ndinya, 2005). They are great source of income to small household farmers especially to women in rural areas who are habitually involved in cultivating and sale of the vegetables (Schippers, 2000). These indigenous vegetables are generally cultivated in small scale and gardens for household consumption and in few places cultivated in large scale for commercial purposes (Maina & Mwangi, 2008). The most common African indigenous vegetables include amaranth (*Amaranthus spp*.), night shade (*Solanaceae spp*), Jute mallow (*Corchorus spp*), spider plant (*Chlorophytum comosum*), cowpea leaf (*Vigna unguiculata*), okra (*Abelmoschus esculentus)*, roselle (*Hibiscus sabdariffa*) and African eggplant (*Solanum melongena*) (Keding & Yang, 2009). These indigenous vegetables are highly adaptive to local conditions, tolerant to harsh climate, ensure food security, increasing incomes while improving human health (Maihuri & Rawat, 2013).

Jute mallow (*Corchorus olitorius*) is a significant traditional leaf vegetable with high nutrition levels. This indigenous vegetable is thought to originate from south China (Simmonds, 1979) and commonly found in Asia, tropical and subtropical areas of Africa (Young, 2000). Depending on the location, the vegetable has different names such as *Mlenda* - Tanzania, *Tossa jute* and *Thelele* - South Africa, *Delele* - Zambia, *Egyptian spinach* – Egypt, and *Gusha* – Zimbabwe. Jute mallow is densely produced in arid regions in the Middle East and Africa. In Tanzania, the vegetable is commonly found at Singida, Dodoma and Mororgoro regions. A report by the National Report of Plant Genetic Resource by FAO (2009) reported that there are only nine accessions of unknown species of Jute mallow at the National Plant Genetic Resource Center in Tanzania. Whoever, Jute mallow germplasm collection contains 104 accessions of different species of Jute mallow from different countries around the world. Still, there is a need to expand in research and documentation of this vegetable given its vast amount of importance.

Jute mallow is the second most significant fiber crop after cotton in terms of availability, usage, production and global consumption (Basu & Roy, 2008). Jute mallow has high levels of vitamins A, B, C and K. It is also rich in copper and iron up to 7.7 mg/100 g. The plant is praised with its contribution to good eyesight (Keding & Yang, 2009). In addition, Jute mallow is a source of various amino acids such as Tryptophan, Threonine, Isoleucine, Leucine, Lysine and Methionine (Maina & Mwangi, 2008). Its leaves and stems are consumed boiled, stew, stir-fried or in soup.

Jute mallow has several other useful roles apart from the rich nutritional base. The roots of Jute mallow are used in treatment of gonorrhea, abdominal pains, pregnancy problems and provide relief of toothache (Maina *et al.*, 2011). Also, the leaves and the seeds of these vegetable have antibacterial properties and used for fever treatment. The fiber from Jute mallow is waterproof and very strong thus used to manufacture clothes, burlap sacks and furnishings. In crop relations Jute mallow has been reported to provide healthier plants that are resistant to diseases and damage by pest when intercropped with other crops (Palada & Chang, 2003).

Despite its importance, in Tanzania Jute mallow is still grown at a lesser extent with improper farming practices and poor combination. Sometimes, grows as a volunteer crop in farmers' fields. Intercropping Jute mallow with other plants provides a possibility of increasing productivity per unit area (Willey, 1990). Farmers will earn greater yield in the same piece of land by making use of the resources that would not be utilized by a single crop in terms of space and nutrient consumption. Not only that but also intercropping the plant gives more control on weeds and pests in the farmers' fields as described by different literatures (Banik, Midya, Sarkar, & Ghose, 2006; Gebru, 2015; Singh *et al.*, 2017; Vlachostergios *et al.*, 2018). This study aimed at maximizing land use and land resources by intercropping Jute mallow with commonly grown cereals such as Maize, Sorghum and Finger millet.

1.2 Statement of the Problem

The status of Jute mallow in Tanzania is underprivileged as it is mostly considered as a poor man's vegetable crop despite its high nutritional base (Peter, 2008). The crop usually receives no management and grows in the farmers' fields as a volunteer crop (Ojiewo *et al.*, 2013). In addition, the agronomic performance of the crop in different intercropping systems has not been characterized. Cropping system exploits natural resources and enhances productivity per unit area depending on the partial and temporal arrangements of crops (Singh & Shivakumar, 2010).

To explore its full potential, there was an urgent need to assess the yield and viability of Jute mallow intercropped with different cereals so that farmers can optimize returns from crop investment on land. It is very clear that the agricultural land is decreasing day after day due to the increasing population size which exert cultivation pressure on small piece of land (Waisanen & Bliss, 2002; Boserup, 2017). Promotion towards production and consumption of indigenous vegetables could assist in lessening food insecurity and alleviate malnutrition in developing countries with reference to the growing population (Cordeiro, 2013).

Intercropping system provides insurance against total crop failure and financial loss (Singh *et al.*, 2001) and involves benefits associated with yield advantages such as efficient use of growth factors and better use of radiant energy (Matusso *et al*., 2012), improving soil fertility (Seran & Brintha, 2010), weeds and pest suppression (Baumann *et al.*, 2000; Smith & McSorley, 2000) and efficient use of water and soil nutrients (Willey, 1990; Sullivan, 2003). This study attempted to assess different intercropping combinations of cereals with Jute mallow so as farmers can maximize land and crops resources utilization. Furthermore, this study was aimed at generating information on the economic returns and nutritional content of the intercrop output of Jute mallow with different cereals.

1.3 Rationale of the Study

Intercropping demonstrates a high potential of crop to crop interaction for the better and higher quality and quantity of food, for man, feed for animals, quality raw materials for good environmental sustainability. Along increasing food supply, farmers' welfare and nutritive consumption, there are different indigenous vegetables that can be included for cultivation and Jute mallow being one of them. This study provides information on Jute mallow and its compatibility with Maize, Sorghum and Finger millet in an intercropping system in the study area. The study results can be used by policy makers in advocacy and extension programs to promote Jute mallow production.

1.4 Objectives of the Study

1.4.1 General Objective

To evaluate the performance of Jute mallow in different intercropping combinations so that farmers can maximize land use and crop resources for improved crop productivity, nutrition and income.

1.4.2 Specific objectives

(i) To assess the growth characteristics and yield response of Jute mallow under Maize, Sorghum and Finger millet intercrops.

(ii) To determine the nutritional contents (crude protein, vitamin C and A, crude fibers, N, P, K, Zn, Na, Fe, and antinutrients) of Jute mallow produced under different cropping systems.

(iii) To estimate cost of production, Marginal Rate of Return and Land Equivalent Ratio of Jute mallow grown under Maize, Sorghum and Finger millet intercropping combinations.

1.5 Hypothesis

Hi: There is a variation in the growth performance, yield, nutrition and economic gain per unit area of Jute mallow under different intercrops.

Ho: There is no statistical difference in the growth performance, yield, nutrition and economic gain per unit area of Jute mallow under different intercrops.

1. 6 Significance of the Study

This study promotes the utilization of indigenous vegetable (Jute mallow) since it can now be incorporated in the existing farming system through intercropping. The study provides information on a sustainable way to increase farmers output, incomes and nutrition. It also lays a foundation for further research on jute mallow and provides information that can be used by extension officers and policy makers in advocacy programs. Last but not least this study highly contributes to my career development as a researcher.

1.7 Delineation of the Study

This study followed a randomized complete block design with three replications and seven treatments to assess the effect of intercropping Jute mallow with commonly grown cereals (Maize, Sorghum and Finger millet) on growth, yield, nutritional contents, antinutritional contents and economic benefit. The study involved one variety of each crop, compared different intercropping combinations of Jute mallow with cereals and associated the performance of the crops in two different locations (Dodoma and Arusha).

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution of Jute mallow

Jute mallow (*Corchorus olitorius*) is one of the indigenous vegetables that belongs to genus *Corchorus* and family *Tiliaceae*. It is thought to originate from south China but now commonly distributed in Tropical Asia and Africa (Simmonds, 1979). It is commonly known by different names depending on the location such as *Mlenda* - Tanzania, *Tossa jute* and *Thelele* - South Africa and Malawi, *Delele* - Zambia, *Egyptian spinach* – Egypt, and *Gusha* - Zimbabwe. Jute mallow is densely produced in arid regions in the Middle East and Africa in general and countries that are highly involved in production of this vegetable include Southern Asia, Egypt, Japan, India, China, Palestine, Syria, Lebanon, Jordan, Nigeria and Tunisia. It has been a leading leaf vegetable in Côte d'Ivoire, Nigeria, Benin, Cameroon, Kenya, Sudan, Zimbabwe and Uganda. Some countries in Asia like China, India and Bangladesh cultivate it for its fiber (Palada & Chang, 2003). The crop requires a warm, humid climate as well as a well-drained sand-loam soil.

Indigenous vegetables are local vegetable species in specific locations that have high significance in sustainability of economies (increase farm income), traditional diets and social systems (Keatinge *et al.*, 2015). These species are vulnerable to extinction and therefore need more recognition and investment in terms of agriculture research and development than they have at the present time (Wang *et al.*, 2014).

Mostly Jute mallow is grown under small-scale in-home gardens for family consumption and little is left for urban consumption (Abukutsa, 2003). The vegetable has high nutritive value, medicinal value and other different uses making its potential for production not only for domestic consumption but also producing surplus for export. The vegetable has been highly neglected in the aspects of research on the fields of agronomy and improvement on its production (Ndinya, 2005). According to Masarirambi *et al.* (2011), Jute mallow is a potential vegetable that can be grown either as a sole crop or intercropped with other common food crops like Maize and Sorghum.

2.2 Jute Mallow Farming

Jute mallow is cultivated in different parts of Asia and Africa. At global level, the production of Jute mallow is generally low despite high nutritive value, less dependence on fertilizers, low moisture tolerance (Dhar *et al*., 2018) non-vulnerability to pest and diseases and its ability to adapt to several climates.

Jute mallow is commonly propagated by seeds. The crop is cultivated at different environment nowadays. It requires an optimum temperature ranging from 25-30 ^{o}C. The crop doesn't perform well in temperatures below 15 °C and like many other crops, extreme drought can kill the crop. It requires rainfall ranges of 600-1200 mm and grow healthy in warm humid areas. Rich well drained loam soil of pH ranging from 4.5 to 8.2 is ideal but the crop can nourish in many soil types. Extreme pH values reduce iron availability to the plant and results to yellowing of leaves (Palada & Chang, 2003). The crop needs enough sunlight and moist soil but not water logged.

2.3 Nutritional, Medicinal and Economical Importance of Jute Mallow

Jute mallow (*Corchorus olitorius*) has high nutritional, medicinal and economic importance to the society. Its ease to cook, palatability and nutritional content pulls more interest to the local demand (Maina *et al.*, 2011). Different parts of Jute mallow from the leaves, stem, fruit, seeds, fiber to the roots have their significance. The roots of the Jute mallow are used as a tonic and a relief for tooth ache (Schippers, 2000). The seeds can be used to treat fever and have antibacterial properties. Jute mallow has also shown efficiency in curing gonorrhea, chronic cystitis, dysuria, enemas and act as a remedy for heart diseases (Schippers, 2000). When the fruit of Jute mallow is immature, it can be dried and ground into powder then used in sauce preparation. The leaves as well are dried and grind into powder for consumption as tea ingredient; they are also used to thicken soup (Maina *et al.*, 2011).

Jute mallow has high nutritional content, the leaves are rich in iron, protein, beta-carotene, riboflavin, thiamin, calcium, vitamin C and E, folate and full of dietary fibers (Kinabo *et al*., 2004). Due to high iron content in Jute mallow leaves, it has been a very good source of nutrient to lactating mothers and children under the age of five. The mucilage from *C. olitorius* is a good source of oils, fatty acids and waxes (Keding & Yang, 2009).

Apart from that Jute mallow produces strong fibers that are waterproof making it perfect for producing burlap sacks, furnishings and even clothes (Keding & Yang, 2009). It has also been reported that rotating Jute mallow with other crops results to healthier plants which are even more resistant to damage by pests (Schippers, 2000). Therefore, this reduces the cost of inputs to local farmers by decreasing the need and amount of pesticides. Similarly, the fact that the plant has tap root system, it enhances nutrient cycle by pulling up nutrients to the surface layer of the soil and hence can easily be consumed by other plants (Adediran *et al*., 2015).

2.4 Intercropping System for Sustainability

The population of the world is exponentially growing and so is food requirement. There is a need for adopting strategies that will intensify land use and labour efficiency to increase productivity per unit area in a sustainable way. One of the strategies is growing different crop types in a close proximity for the aim of yield increment through maximum utilization of the planting space (Anders *et al.*, 1995). Intercropping system refers to a planting method that encompassing growing two or more crops alongside one another in the same growing season (Mousavi & Eskandari, 2011). The yield increase in intercropping is a function of reduced weeds, pests and diseases, high growth rates and effective resource use (Mousavi & Eskandari, 2011). Contrary to monocropping, intercropping acts as insurance against total crop failure and helps mass exploration of soil nutrients which eventually results to soil biological efficiency (Francis, 1989). Selected crops for intercropping have to be compatible and compatibility of crops in intercropping system depends on plant growth habits and ability to utilize the available resources such us space, water, solar power and soil nutrients (Seran & Brintha, 2009). Intercropping may reduce yield of individual crop in the system but have a better cumulative yield of all crops together. Shading, plant density and nutrient competition are among common factors that may reduce yield of individual crops in intercropping system. These factors could be minimized by proper spacing arrangements and use of crops that best utilize soil nutrients (Francis, 1989).

Component crops in intercropping system are able to utilize natural resources effectively more than when grown separately. A study by Seran and Jeyakumaran (2009) reported that competition on nutrients and light caused a decrease in number of pods per plant of capsicum vegetable when intercropped with cowpeas. Another study on Maize intercropped with okra revealed a decrease in okra number of leaves per plant due to light and nutrient competition

(Muoneke & Asiegbu, 1997). The same was observed when brinia was intercropped with groundnut (Prashaanth *el al*., 2009). Also, growth and yield of individual crops in an intercropping system could be increased as a result of interspecific facilitation between the crops. Maize intercropped with okra recorded best okra yield and yield components (Muoneka & Asiegbu, 1997). A study by Ijoyah and Dzer (2012) reported decrease okra yield when intercropped with Maize but increased Maize yield at 50 000 plant density per hectare of Maize. Intercropping has also been reported to increase soil nutrients, nutrition and nutrient uptake in plants. Maize intercropped with cowpea showed increased nitrogen phosphorus and potassium content than their mono-cropped stands (Dahinardeh el *al.,* 2010). Another study reported efficient nutrient uptake when corn was intercropped with rice and with soybean than their respective sole stands (Suryanta & Harwood, 1976). Higher economic returns from intercropping system is one of the benefits of intercropping. A study by Oseni (2010) reported higher income and better land use when Sorghum was intercropped with cowea than sole stands of each crop. Also, Charles *et al*. (2011) reported high economic returns from Finger millet - *Desmodium intortum* intercropping system as compared to sole stands of individual crops. This is a result of better and efficient resource utilization (Seran & Brintha, 2009). Several studies on intercropping have reported higher net return from intercropping than monocropping system (Ijoyah & Dzer, 2012; Sharma & Tiwari, 1996; Khatiwada, 2000; Brintha & Seran, 2009). Thus, intercropping is a sustainable practice which is associated with better total yield, nutrient balance and higher return on investment.

2.5 Jute Mallow in Intercropping System

Studies on cereal-vegetables intercrops show that yield advantage, weed control and high monetary return can be obtained from the associations (Ijoyah, 2012). Especially in the tropics the system helps to provide full soil cover throughout the year and provide some biological, socio-economic and ecological advantages over the monocropping system (Sadashiy, 2004; Maluleke *et al.,* 2005).

Research was done on okra which is a related specie to Jute mallow, intercropped with Maize and positive results were obtained. Best okra yields were obtained in the intercrop association as compared with the monocrop stands (Ijoyah & Dzer, 2012). This gives room to practice intercropping on Jute mallow expecting a positive output as well. Additionally, a study conducted by Sarkar, Majumdar and Kundu (2013) showed that there was an increase in total equivalent yield of Jute as a fiber crop in a strip crop association with rice under an interrow spacing of 20 cm.

In a different setting, Jute mallow was intercropped with papaya and showed a yield increment for papaya. The LER of papaya intercropped with Jute mallow was 1.60 which indicates that the intercropped stands are more advantageous than mono-cropping. The study also indicated that the monetary value of the mixture is advantageous (Aiyelaagbe & Jolaoso, 1992).

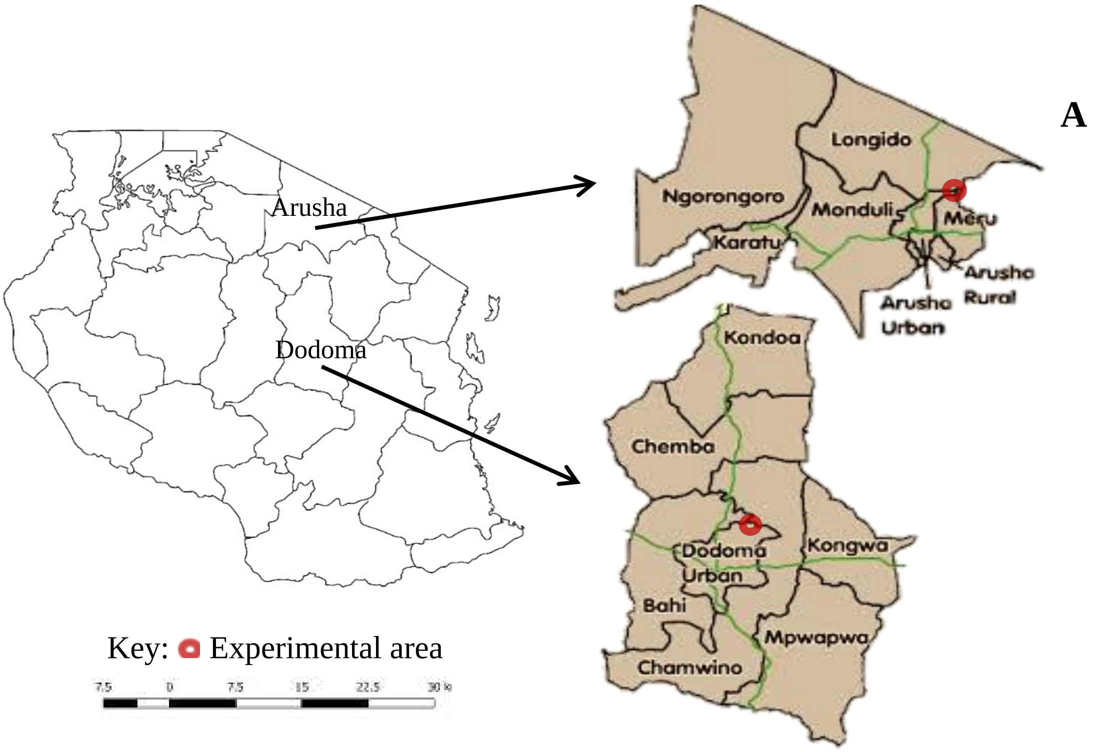
Studies have further shown that there is a quality increase in nutritional composition of crops grown under intercropping system as compared with sole crop system. Maize intercropped with Mungbeans showed an increase in its crude protein yield as compared with the monocrop stands (Hamdollah, 2012). Also, two African indigenous vegetables, African Nightshade (*Solanum scabrum*) and Ethiopian Kale (*Brassica carinata*) were intercropped under greenhouse conditions. Secondary metabolites were positively affected by intercropping system as high levels of glucosinolate were observed in *B. carinata*. It also maintains the biomass production and minerals accumulation. Nutritional content and phytochemical composition of a plant can be altered by cropping system (Keding & Yang 2009; Ngwene *et al.*, 2017). Therefore, there is expected change in quality of Jute mallow yield at different cropping systems. In this study, Jute mallow was intercropped with different cereals (Maize, Sorghum and Finger millet) to determine the performance and changes in yield, nutritional quality and economic returns of Jute mallow as sole crop and when intercropped.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Field experiments were conducted at farms of Nelson Mandela African Institution of Science and Technology (NM-AIST) in Arusha and Hombolo Agricultural Research Center in Dodoma, Tanzania. The NM-AIST farm in Arusha is located at latitude -3^o 24’ South and Longitude 36^o 47’ East at an altitude of 1168 m.a.s.l., the Hombolo Agricultural Research Center is located at latitude 5^{o}54’29” S and longitude 35^{o}57’36” E, altitude of 1020 m.a.s.l. Data on rainfall and temperature was sourced and compiled from world weather online. Rainfall and temperature conditions of the study site are as shown in Fig. 1(b).



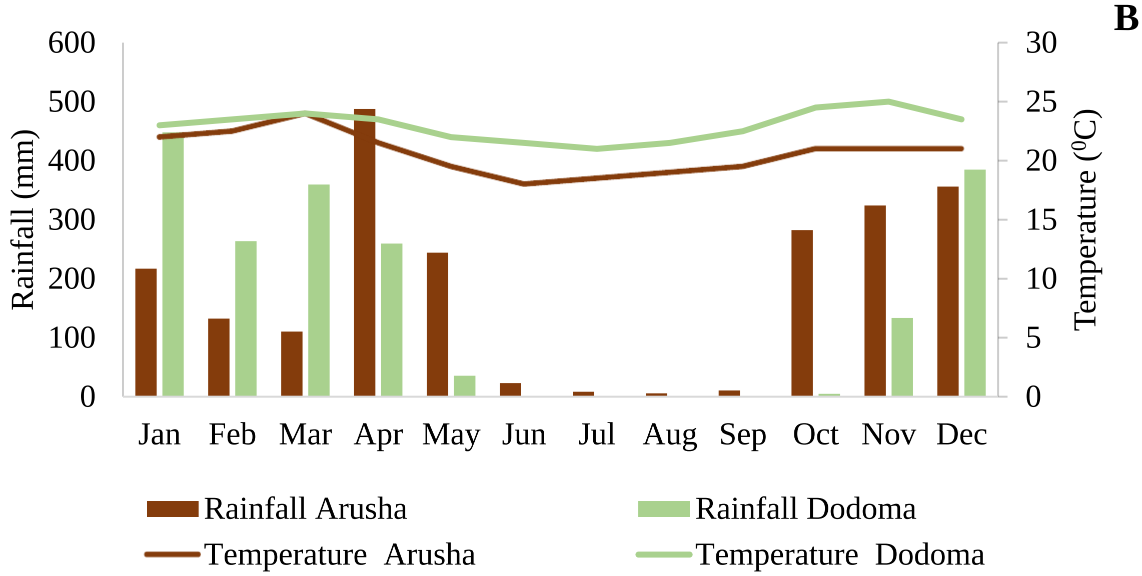


Figure 1: (a) A map showing the study area (Field survey, 2019) and (b) A graph showing amount of rainfall and temperature of the study area for the growing season 2019/2020 (World Weather Online, 2019)

3.2 Study Materials

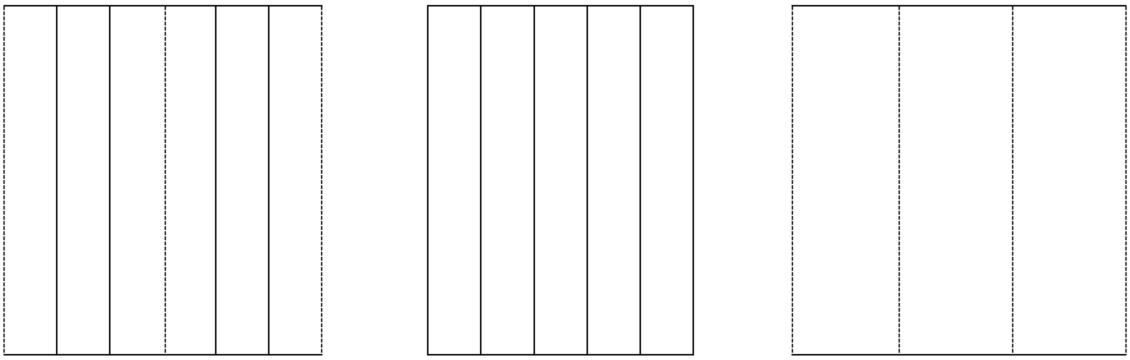
The study involved Jute mallow intercropped with Maize, Sorghum and Finger millet. Accession "*Sudan 2*" was used as it recorded better leaf yield performance following the study conducted by Ngomuo (2017). Jute mallow seeds used in this study were obtained from World Vegetable Center- Arusha. For the cereals, commonly grown varieties with good yield performance in the Central and Northern zone of Tanzania were obtained under recommendation from respective Agriculture Research Centers. Varieties used for Sorghum, Maize and Finger millet were *Macia, UHS 401* and *U15* respectively. Sorghum seeds were obtained from Ilonga Agricultural Research Institute and those of Maize and Finger millet were obtained from Uyole Agricultural Research Institute.

3.3 Experimental Design and Establishment

The experiment followed a randomized complete block design (RCBD) with three replications in two different locations. In each block, there were seven treatments namely; (T1) Jute mallow intercropped with Maize, (T2) Jute mallow intercropped with Sorghum, (T3) Jute mallow intercropped with Finger millet (T4) Sole Jute mallow, (T5) Sole Maize, (T6) Sole Sorghum, (T7) Sole Finger millet. The experiment was set on 5 March 2019 in Dodoma and on 3 April 2019 in Arusha. In each site, the land was prepared by clearing, ploughing and layout before plantation. Plot size was 3 m x 3 m. Each treatment plot was separated by 1m between treatment and 2m apart between blocks. The cereals followed the interrow spacing of 75 cm and intra-row spacing of 60 cm. Three seeds were sown per hill and thinned to two plants after emergence. To intercrop Jute mallow, two rows were included between each cereal crop used in the experiment. To maintain similar plant population per ha, spacing of Jute mallow was 25 cm x 16 cm for intercropped stands and 20 cm x 20 cm for sole Jute mallow treatment as recommended by Sarkar *et al.* (2013). Three seeds were sown per hill and thinned to two plant after emergence. Plants were irrigated throughout the growing season.

3.4 Cropping Layout

The intercropping pattern was arranged in the following layout with the treatments being allocated randomly.



Intercropped stands

Sole planted Jute mallow

Sole planted cereals

Key: ——— Jute mallow (Sole stand 20 x 20 cm, intercropped stand 25 x 16 cm)

- - - - - - Cereals (75 x 60 cm)

3.5 Sampling and Data Collection

Soil samples were collected for lab analysis. Five soil samples of 500 g each were randomly taken from the experimental fields at a depth of 0-30 cm, packed in sample bags and taken to the lab for analysis. The soil was then analysed for chemical and physical properties as shown in Table 2. Sampling for Jute mallow was done on plants growing at the four central rows in each plot, while for cereals sampled plants for data collection were taken from the three central rows of each plot. Four plants were randomly selected from each plot for data collection. Data collected on Jute mallow included; plant height, number of branches, number of leaves, stem diameter, leaf length, leaf width, canopy size and days to 50 % flowering, fresh and dry leaf yield, number of pods, number of seeds per pod, seeds yield and 1000 seed weight. Data on growth parameters was collected six weeks after planting during leaf harvest. Leaf harvest was done on middle rows of half of each plot and the other half was left for data on days to 50 % flowering and seed yield. Harvested leaves were solar dried for six hours and oven dried at 60 ^{0}C for two days. Data collected on Maize included; plant height, 1000 seed weight, cobs per plant, number of seeds per cob, cob weight per plant, seed weight per cob and seed yield per plant. For Sorghum the collected data included plant height, panicle length, panicle weight, 1000 seed weight and seed yield per plant. Data collected on Finger millet included; plant height, 1000 seed weight, panicle weight, seed weight per panicle and seed yield per plant.

3.6 Data Handling

The data collected was further manipulated for further results as shown below.

Plant moisture content (MC) percentage was obtained by the following formula;

$$\text{MC}\,\% = 100(\text{Leaf fresh weight} - \text{Leaf Dry weight}) \,/\, \text{Leaf fresh weight}$$

Assessment of advantages of the intercrops over sole crops was obtained by calculating the Land Equivalent Ratio (LER). It is a tool used to assess and evaluate the competition of intercrop systems. It was calculated by the following formula;

$$\text{LER} = \frac{\text{intercrop Jute mallow}}{\text{sole Jute mallow}} + \frac{\text{intercrop cereal}}{\text{sole cereal}}$$

When the value of LER>1 = there is a yield advantage of farming as intercrops rather than monocrops. LER<1 = there is a yield advantage of farming as monocrops rather than intercrops. When LER=1 means that there is no difference on the yield of intercrops and monocrops of the crops. Therefore, LER shows the effectiveness of intercropping system on utilizing the surrounding resources in the same piece of land in comparison with mono-cropping system (Fetene, 2003; Wahla *et al*., 2009).

Dried leaf samples of Jute mallow were taken to Sokoine University of Agriculture laboratory for analyzing its nutritional content. The samples were ground into powder for analysis of macro and micro nutrients, and anti-nutrients. Nutrients that were analysed included crude proteins, vitamin C, beta carotene, crude fiber content and minerals (N, P, K, Zn, Ca, Na and Fe). Anti-nutrients analysed included tannins, phytates and oxalates content. Table 1 shows the list of methods and principles used for each parameter analysed.

Table 1: Methods and principles used to analyse the respective nutritional parameter

Parameter	Methods	Principles
	Nutritional parameters	
Nitrogen and crude protein	ISO 20483:2013	Titrimetric, Kjeldahl digestion (Aina *et al.*, 2012)
Crude fiber	ISO 5498:1981 (B.5 Separation)	Gravimetric (Aina *et al.*, 2012).
Beta carotene	AOAC 960.45	Spectrophotometry (Rodriguez-Amaya & Kimura, 2004)
Vitamin C (Ascorbic acid)	AOAC 967.21 2,6 dichloroindophenol titrimetric method	Titrimetric (Nielsen, 2010)
Minerals	AOAC 990.05 ISO 8294:1994; or AOCS Ca 18b-91 (03) (Codex general method)	Atomic absorption Spectrophotometry -direct graphite furnace (Ngozi & Nkiru, 2014).
	Antinutritional parameters	
Tannins	Folin Ciocalteu method Spectrophotometric	Spectrophotometry (Kamath *et al.*, 2015)
Oxalate	ISO 8467:1993. Redox reaction with potassium permanganate	Titrimetric (Makkar *et al.*, 2007)
Phytate	Based on Precipitation of Phytate	Spectrophotometry (Makkar *et al.*, 2007)

The economic value of the experiment was obtained by calculating the Marginal rate of return. Marginal net return shows how the revenue has covered the variable cost of production. The variable cost was subtracted from the product of the total leaf yield obtained and the prevailing market price for Jute mallow. The following formula was used for such calculations:

Marginal net return (MNR) = $Y \times P - TVC$

Y = Yield in kg per ha P= Prevailing market price in USD per kg

TVC= Total Variable Cost (in USD) involved all expenses during the production process (labour, seeds, fertilizer, rent etc.)

The marginal rate of return for each treatment was calculated. The marginal rate of return (MRR) showed the economical effectiveness of investing in one treatment over the other. It was obtained by the following formula;

$$MRR \text{ (Marginal Rate of Return)} = \frac{MNR\text{(Marginal Net Return)}}{TVC\text{(Total Variable Cost)}}$$

3.7 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using STATISTICA software (version 10.0) to test the effect of the treatments of the study. Treatment means were separated using the Fisher's Least Significance Difference (LSD) test at p = 0.05 level of significance.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Soil properties of the experimental areas

During the setting of the experiment, the soils pH was 6.04 and 6.41 for Arusha and Dodoma respectively (Table 2). The values of Nitrogen (0.1%), Phosphorus (21.3 mg/kg) and Potassium (3.35 Cmol/Kg) in Arusha were relatively higher than Nitrogen (0.09%) Phosphorus (15.1 mg/kg) and Potassium (0.83 Cmol/Kg) in Dodoma. As seen in Table 2 on all other soil parameters measured, the soil at Arusha was more fertile than at Dodoma. Soil texture were Clay loam and Sandy-loam in Arusha and Dodoma, respectively.

Table 2: Chemical and physical properties of the soil samples from the experimental areas

Soil properties	Dodoma	Arusha
Soil pH	6.04	6.41
C (%)	0.45	2.09
Total N (%)	0.09	0.10
C:N	5.04	25.1
Ext P (Mg/Kg)	15.1	21.3
CEC (Cmol/ Kg)	9	15.20
Ca^{++} (Cmol/Kg)	2.46	24.78
Mg^{++} (Cmol/Kg)	0.85	6.65
Na^{+} (Cmol/Kg)	0.14	0.27
K^{+} (Cmol/Kg)	0.83	3.35
Particle size distribution		
(%) Sand	65.50	30.44
(%) Clay	30.00	37.20
(%) Silt	4.50	32.36
Textural class	Sandy clay loam	Clay loam

N= Nitrogen, P= Phosphorus, K= Potassium, C= Organic Carbon, CEC= Cation exchange capacity, Mg= Magnesium, Na= Sodium and Ca= Calcium.

4.1.2 Growth parameters of Jute mallow intercropped with Maize, Sorghum and Finger millet

The results showed that site effect ($p \leq 0.05$) was significant on number of branches, number of leaves, leaf length and leaf width (Table 3). Jute mallow performed significantly higher in Dodoma than Arusha on number of branches (8.5 plant^{-1}) and number of leaves (82 plant^{-1}).

On the other side Arusha had significantly higher values of leaf length (7.75 cm) and leaf width (3.47 cm) than Dodoma. Treatment effect was significant ($p \leq 0.05$) for plant height, number of branches, number of leaves, stem diameter, leaf length, leaf width and canopy size (Table 3). Jute mallow with Maize intercrop significantly suppressed ($p \leq 0.05$) the growth of Jute mallow in plant height, number of branches, number of leaves, stem diameter and leaf length as compared with sole Jute mallow and Jute mallow intercropped with Sorghum and Finger millet. Even though sole Jute mallow had higher values, intercropping did not significantly affect ($p \leq 0.05$) the growth of Jute mallow (plant height, number of branches and leaf length) intercropped with Sorghum and Finger millet. Stem diameter was significantly ($P \leq 0.05$) reduced when Jute mallow was intercropped with Sorghum (0.55 cm) and Maize (0.55 cm). Jute mallow-Sorghum intercrop significantly ($P \leq 0.01$) increased leaf width (3.2 cm). Jute mallow intercropped with Sorghum had the highest value (28.18 cm) of canopy size which was significantly different from Jute mallow with Maize intercrop and at par with sole Jute mallow and Jute mallow with Finger millet intercrops. Intercropping did not affect the growth of Jute mallow when intercropped with Sorghum and with Finger millet in plant height, number of branches, number of leaves, leaf length and canopy size (Table 3). Site-treatment interaction was significant ($P \leq 0.01$) on leaf length (Table 3). Leaf length was reduced significantly ($P \leq 0.05$) by intercropping in Arusha and showed no significant difference in Dodoma (Fig. 2).

Table 3: Plant growth parameters of Jute mallow intercropped with cereals (Maize, Sorghum and Finger millet) at six weeks after planting

Treatments	Height (cm)	Number of branches	Number of leaves	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Canopy (cm)
Site							
Arusha	66.62±2.61a	7.03±0.24b	75.23±1.90b	0.57±0.01a	7.75±0.19a	3.47±0.04a	26.35±0.67a
Dodoma	62.51±3.22a	8.5±0.47a	82±3.84a	0.59±0.02a	6.89±0.17b	2.47±0.07b	26.83±0.66a
Cropping system							
Jute mallow +Maize	44.59±1.67b	5.58±0.24b	60.98±1.21b	0.55±0.02b	6.86±0.21b	2.87±0.18b	24.44±1.08b
Jute mallow +Sorghum	69.42±2.62a	8.13±0.54a	81.75±4.08a	0.55±0.02b	7.32±0.27ab	3.2±0.16a	28.18±1.02a
Jute mallow +Finger millet	70.56±2.56a	8.59±0.52a	85.9±3.27a	0.58±0.02ab	7.34±0.19ab	2.98±0.15b	27.74±0.67a
Sole Jute mallow	73.69±2.79a	8.76±0.41a	85.81±3.67a	0.64±0.02a	7.76±0.38a	2.84±0.18b	26±0.50ab
2-Way ANOVA F-statistics							
Site	2.793 ns	14.93***	4.93*	1.179 ns	15.67***	177.84***	0.342 ns
Treatment	29.81***	15.06***	15.29***	4.16*	2.86*	4.79**	4.34**
Site* Treatment	0.271 ns	1.420 ns	1.708 ns	0.893 ns	4.60**	1.502 ns	2.221 ns

Values presented are means ±SE. Different letter(s) within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ respectively.

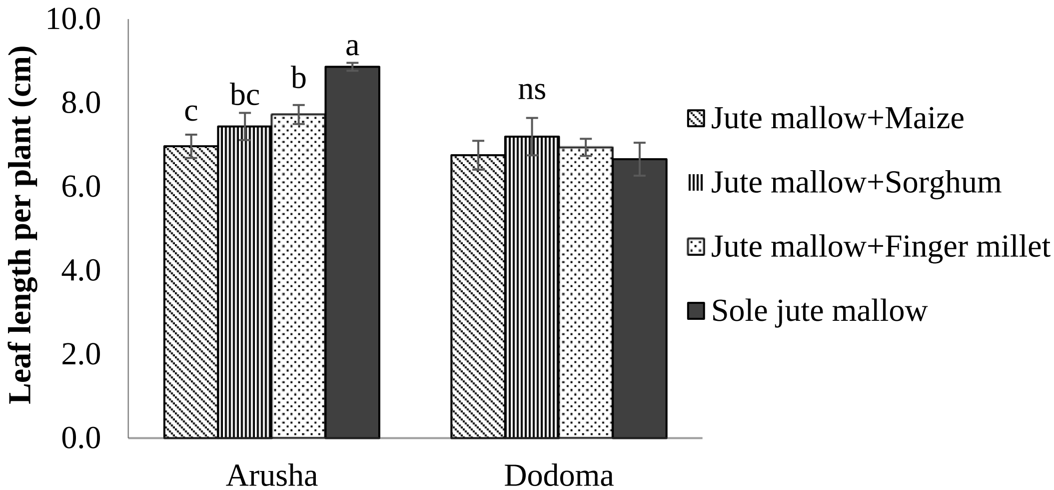


Figure 2: Site-treatment interaction on leaf length per plant of Jute mallow at six weeks after planting

4.1.3 Days to 50 % flowering, moisture content and biomass yield per plant of Jute mallow when intercropped with Maize, Sorghum and Finger millet

Site effect was found significant ($P \leq 0.01$) on biomass yield per plant where by Arusha (42.9g) was higher that Dodoma (34.95 g) (Table 4). Treatment effect was significant ($P \leq 0.001$) for days to 50 % flower and biomass yield per plant. Moisture content was not significantly ($P \leq 0.01$) affected by intercropping. Intercropping significantly ($P \leq 0.001$) increased the number of days to 50 % flowering from 53.5 days in sole Jute mallow to a range of 55.67 to 59.75 days among intercropped stands. Comparing with other intercropped stands, Jute mallow intercropped with Finger millet (55.67 days) had the shortest number of days to 50 % flowering while Jute mallow intercropped with Maize significantly recorded the longest number of days to 50 % flowering (59.75 days). Jute mallow with Maize and with Finger millet intercrops significantly suppressed biomass yield per plant of Jute mallow to 32.32 g and 33.83 g respectively. The highest value of biomass yield per plant was from sole Jute mallow (45.16 g) followed by Jute mallow intercropped with Sorghum (44.4 g) (Table 4).

Table 4: Days to 50 % flowering, moisture content and biomass yield of Jute mallow under cereal (Maize, Sorghum and Finger millet) intercrops

Treatments	Moisture content (%)	Days to 50 % flowering	Biomass yield per plant (g)
Site			
Arusha	57.68±2.32a	56.3±0.60a	42.9±2.59a
Dodoma	56.36±1.59a	56.21±0.57a	34.95±1.88b
Cropping system			
Jute mallow+ Maize	57.97±2.90a	59.75±0.71a	32.32±3.08b
Jute mallow+ Sorghum	53.2±3.04a	56.09±0.45b	44.4±3.70a
Jute mallow+ Finger millet	61.97±3.09a	55.67±0.33b	33.83±2.59b
Sole Jute mallow	54.95±1.44a	53.5±0.47c	45.16±2.47a
2-Way ANOVA F-statistics			
Site	0.223ns	0.02 ns	7.79**
Treatment	1.893ns	23.63***	5.69***
Site* Treatment	0.355ns	0.01 ns	0.3187 ns

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher's Least Significance Difference test. ns=Non significant, **, *** = Significant at $p \leq 0.01$ and $p \leq 0.001$ respectively.

4.1.4. Intercropping effect of cereals (Maize, Sorghum and Finger millet) on Jute mallow leaf and seed yield

Results showed that site effect was significant ($P \leq 0.05$) on plant weight, stem weight, fresh leaf weight and dry leaf weight. Arusha had significantly higher values of Jute mallow on plant fresh weight (102.57 g), stem weight (58.75 g), fresh leaf weight (42.19 g) and dry leaf weight (42.19 g) than Dodoma (Table 5). Treatment effect was significant ($P \leq 0.05$) in plant weight, stem weight, fresh leaf weight and dry leaf weight. Jute mallow with Maize intercrop suppressed plant weight, plant stem weight and fresh leaf weight and dry leaf weight. The study also showed that site effect was significant ($P \leq 0.05$) on pods per plant, pod length, seeds per pod, 1000 seed weight and plant seed yield. Jute mallow in Arusha had significantly higher values on pods per plant (15.44 g), 1000 seed weight (2.35 g) and seed yield per plant (5.3 g) than Dodoma. Pod length (6.38 cm) and number of seeds per pod (161.87) in Dodoma was found significantly higher than Arusha (Table 5). Treatment effect was significant ($P \leq 0.05$) in pods per plant, pod length, seeds per pod and seed yield per plant. Pods per plant and seeds per pod of Jute mallow were suppressed when Jute mallow was intercropped with Maize. Seed yield per plant of Jute mallow was negatively affected by intercropping. Moreover, intercropping effected negatively pod length (5.74 g) and plant seed yield (4.9 g) in Jute mallow and Finger millet intercrop (Table 5). Site-treatment interaction was significant ($p \leq 0.05$) in number of seeds per pod, 1000 seed weight and plant seed yield (Fig. 3). Intercropping had a negative effect of on number of seeds per pod in Dodoma. Plant seed yield and 1000 seed weight were suppressed by Jute mallow with Maize and Finger millet intercrops in Arusha. Jute mallow intercropped with Finger millet had significantly higher values of 1000 seed weight and plant seed yield in Dodoma. On the same parameters, Jute mallow with Sorghum intercrop was not affected ($p \leq 0.05$) by intercropping in Arusha (Fig. 3).

Table 5: Response of plant leaf yield and seed yield of Jute mallow when intercropped with Maize, Sorghum and Finger millet

Treatments	Plant fresh weight (g)	Fresh stem weight (g)	Fresh leaf weight per plant (g)	Dry leaf weight per plant (g)	No. of pods per plant	Pod length (cm)	No. of Seeds per pod	1000 Seed weight (g)	Seed yield per plant (g)
Site									
Arusha	102.57±3.83a	58.75±2.43a	42.19±1.86a	17.43±0.92a	15.44±0.46a	5.71±0.08b	144.57±3.31b	2.35±0.07a	5.3±0.30a
Dodoma	79.12±2.77b	45.08±1.95b	32.83±1.21b	14.35±0.73b	13.77±0.36b	6.38±0.11a	161.87±3.35a	2.11±0.06b	4.7±0.21b
Cropping system									
Jute mallow +Maize	75.8±4.53b	43.57±3.18b	30.48±1.75b	12.67±0.96b	13.5±0.56b	5.83±0.07b	143.02±3.48b	2.32±0.09a	4.51±0.31b
Jute mallow +Sorghum	94.98±4.96a	54.78±3.81a	39.92±2.50a	18.21±0.88a	14.67±0.62ab	6.33±0.20a	154.73±4.78ab	2.14±0.10a	4.87±0.38b
Jute mallow +Finger millet	91.94±6.24a	52.6±3.86a	37.89±2.63a	13.92±1.06b	14.51±0.40ab	5.74±0.18b	153.53±7.00a	2.19±0.08a	4.9±0.37b
Sole Jute mallow	100.66±5.31a	56.7±2.98a	41.75±2.39a	18.75±1.12a	15.72±0.77a	6.29±0.12a	161.59±4.48a	2.28±0.12a	5.71±0.37a
2-Way ANOVA F-statistics									
Site	33.19***	22.07***	24.20***	10.00**	10.06**	37.65***	20.48***	9.50**	4.96*
Treatment	6.87***	3.98*	6.75***	10.72***	2.97*	7.70***	4.03*	1.060 ns	3.60*
Site* Treatment	1.461ns	0.267ns	0.822ns	0.348ns	2.431ns	2.22ns	5.94**	6.02**	11.02***

Values presented are means ±SE. Different letter(s) within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

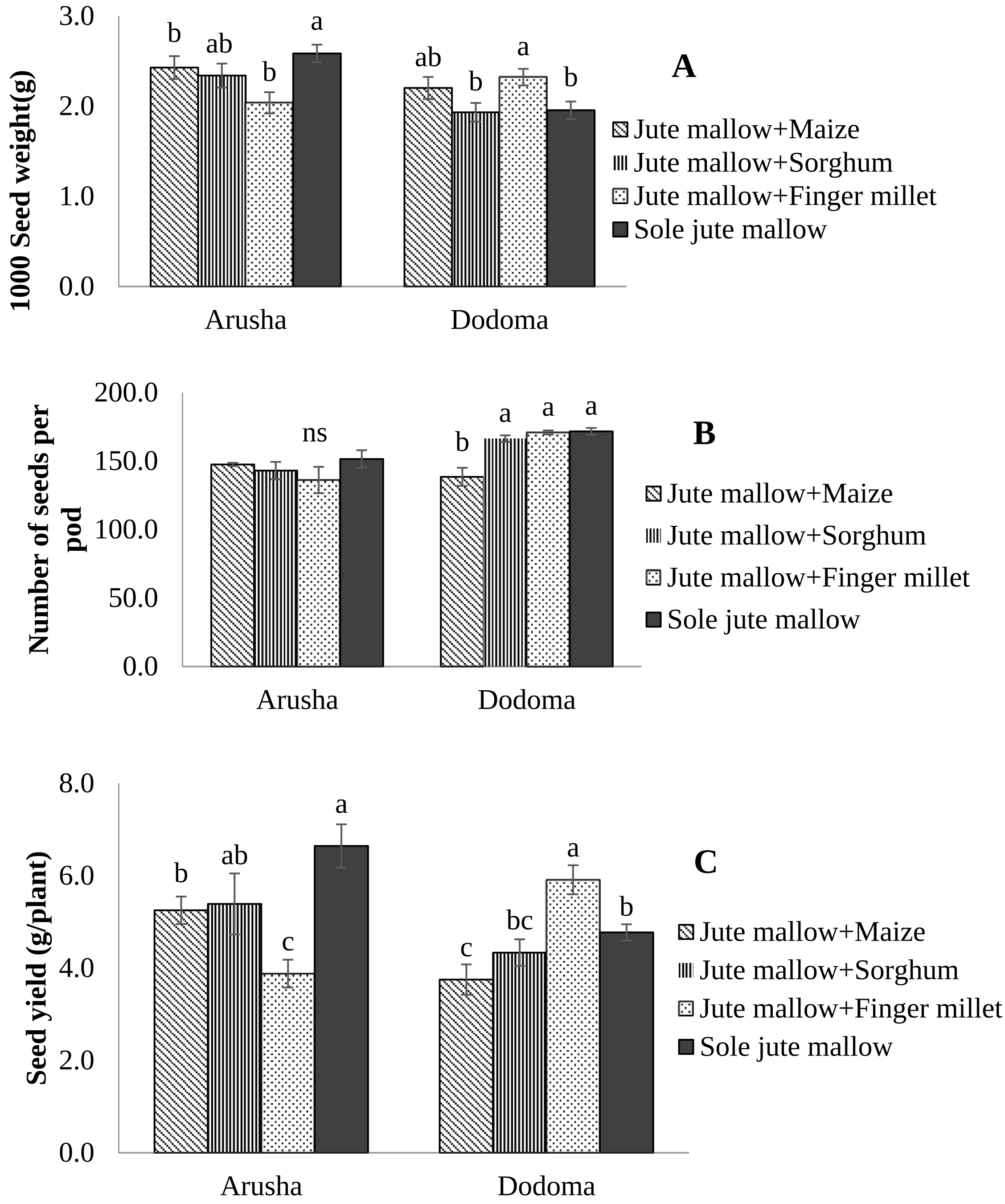


Figure 3: Site-treatment interaction on (A) 1000 seed weight, (B) number of seeds per pod, and (C) seed yield per plant of Jute mallow

4.1.5 Yield performance of cereals (Maize, Sorghum and Finger millet) intercropped with Jute mallow

Site effect and treatment effect was significant ($p \leq 0.05$) for all measured parameters in Maize. Arusha had higher values of plant height (159.12 cm), 1000 seed weight (337.34 g), number of cobs per plant (1.2), number of seeds per cob (400.58), cob weight per plant (50.04 g), seed weight per cob (137.54 g) and yield per plant (169.78 g) than Dodoma (Table 6). Yield per plant of Maize in Arusha was more than twice of Maize in Dodoma (Table 6). Intercropping significantly suppressed plant height (167.47 to 126.25 cm), 1000 seed weight (327.29 to 242.7 g), number of cobs per plant (1.24 to 1), number of seeds per cob (350.73 to 317.81), cob weight per plant (46.62 to 36.96 g), seed weight per cob (118.96 to 81.54 g) and seed yield per plant (153.77 to 81.54 g) of Maize as compared with its sole stands (Table 6).

For Finger millet, site effect was significant ($p \leq 0.05$) for plant height, 1000 seed weight, panicle weight, seed weight per panicle and yield per plant (Table 7). For prior mentioned parameters, Arusha had higher values ($p \leq 0.05$) than Dodoma as seen in table 7. Treatment effect was significant ($p \leq 0.05$) for all measured parameters. Relative to monocropping stands, intercropping significantly reduced plant height at harvest (72.74 to 65.52 cm), number of fingers per plant (5.75 to 4.53), 1000 seed weight (4.02 to 3.12 g), number of tillers per plant (5.66 to 3.9), plant panicle weight (5.42 to 3.8 g), seed weight per panicle (3.45 to 2.28 g) seed yield per plant (19.58 to 8.87 g) of Finger millet (Table 7).

Site effect and treatment effect was also significant ($p \leq 0.05$) for Sorghum in all measured parameters (Table 8). Arusha had higher values ($p \leq 0.05$) of plant height (116.36 cm) and panicle length (22.67 cm) while Dodoma had higher values of panicle weight (45.48 g), 1000 seed weight (3.73 g) and yield per plant (30.46 g) (Table 8). All parameters for intercropped Sorghum presented lower values ($p \leq 0.05$) than sole stands. Intercropping significantly decreased plant height at harvest (112.2 to 102.88 cm), 1000 seed weight (3.87 to 3.1 g), plant panicle weight (54.03 to 32.13 g), length of panicle at harvest (23.02 to 17.74 cm) and seed yield per plant (35.85 to 21.38 g) of Sorghum as shown in Table 8.

Table 6: Response of yield and yield attributes of Maize when intercropped with Jute mallow

Treatments	Plant height at harvest (cm)	1000 seed weight (g)	Number of cobs per plant	Number of seeds per cob	Cob weight per plant (g)	Seed weight per cob (g)	Yield per plant (g)
Site							
Arusha	159.12±9.40a	337.34±16.74a	1.2±0.09a	400.58±9.16a	50.04±3.25a	137.54±9.48a	169.78±20.39a
Dodoma	134.61±4.91b	232.65±10.84b	1.04±0.02b	267.96±7.61b	33.54±1.46b	62.96±3.26b	65.53±4.51b
Cropping system							
Jute mallow +Maize	126.25±2.46b	242.7±14.50b	1±0.00b	317.81±19.73b	36.96±2.79b	81.54±9.32b	81.54±9.32b
Sole Maize	167.47±7.51a	327.29±18.99a	1.24±0.08a	350.73±22.43a	46.62±3.61a	118.96±14.25a	153.77±24.62a
F-statistic							
Site	27.19***	170.96***	6.25*	182.97***	30.21***	212.36***	98.53***
Treatment	76.94***	111.60***	12.25**	11.28**	10.35**	53.45***	47.29***

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

Table 7: Response of yield and yield attributes of Finger millet when intercropped with Jute mallow

Treatments	Plant height at harvest (cm)	No. of fingers per plant	1000 seed weight (g)	Number of tillers per plant	Plant panicle weight (g)	Seed weight per panicle (g)	Seed yield (g) per plant
Site							
Arusha	68.17±1.36b	5.18±0.23a	3.4±0.15b	4.75±0.32a	4.26±0.37b	2.2±0.22b	11.07±1.70b
Dodoma	70.09±1.05a	5.1±0.24a	3.74±0.17a	4.81±0.29a	4.96±0.18a	3.54±0.14a	17.38±1.66a
Cropping system							
Jute mallow + Finger millet	65.52±0.74b	4.53±0.17b	3.12±0.10b	3.9±0.19b	3.8±0.24b	2.28±0.25b	8.87±1.10b
Sole Finger millet	72.74±0.45a	5.75±0.12a	4.02±0.08a	5.66±0.09a	5.42±0.12a	3.45±0.16a	19.58±1.01a
F-statistic							
Site	5.97*	0.120ns	8.40**	0.05	18.97***	722.07***	86.09***
Treatment	84.45***	31.7***	61.261***	45.33***	100.24***	550.07***	248.67***

Values presented are means ±SE. Different letter within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

Table 8: Response of yield and yield attributes of Sorghum when intercropped with Jute mallow

Treatments	Plant height at harvest (cm)	1000 seed weight (g)	Plant panicle weight (g)	Seed yield (g) per plant	Length of panicle at harvest (cm)
Site					
Arusha	116.36±2.97a	3.24±0.15b	40.69±5.17b	26.77±3.36b	22.67±1.07a
Dodoma	98.72±1.69b	3.73±0.12a	45.48±1.96a	30.46±1.50a	18.09±0.81b
Cropping system					
Jute mallow + Sorghum	102.88±3.46b	3.1±0.11b	32.13±2.29b	21.38±1.46b	17.74±0.57b
Sole Sorghum	112.2±3.14a	3.87±0.09a	54.03±2.13a	35.85±1.59a	23.02±1.08a
F- statistics					
Site	37.64***	23.43***	4.90*	4.91*	43.72***
Treatment	10.52**	57.89***	102.13***	75.75***	57.74***

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

4.1.6 LER of intercropping combination of Jute mallow with Maize, Sorghum and Finger millet.

Efficiency of the intercropping system was determined by the LER of each intercropped treatment. The study showed that all intercrops had a LER greater than 1 which means that they all have yield advantages over monocrops (Fetene, 2003; Wahla *et al*., 2009). Jute mallow with Sorghum intercrop had the highest yield advantage with LER of 1.7 and 1.53 for Dodoma and Arusha respectively (Table 9). This means that it requires 70% and 53% more land resource in Dodoma and Arusha to obtain the same yield in mono-cropping. Jute mallow intercropped with Finger millet was found to have the lowest LER of 1.23 and 1.22 in Arusha and Dodoma indicating that there is a yield advantage of 23% in Arusha and 22% in Dodoma (Table 9). However, there was no significant ($p \leq 0.05$) difference of LER. among the intercrops in Arusha.

Table 9: LER of Jute mallow intercrops in Arusha and Dodoma

Treatment/ Site	Arusha	Dodoma
Jute mallow +Maize	1.31±0.12a	1.28±0.06b
Jute mallow +Sorghum	1.53±0.12a	1.7±0.08a
Jute mallow + Finger millet	1.23±0.19a	1.22±0.06b
Level of significance	0.360740	0.000342

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher's Least Significance Difference test

4.1.7 Nutrients of Jute mallow intercropped with Maize, Sorghum and Finger millet

Results of this study showed that site effect and treatment effect was significant ($p \leq 0.01$) for ß-carotene, crude protein, crude fibers and vitamin C. For all mentioned parameters, Arusha had higher values than Dodoma site (Table 10). Jute mallow intercropped with Finger millet significantly ($p \leq 0.001$) had the highest ß-carotene (6.41 %), crude protein (23.13 %) and crude fibers (30.09 %). Intercropping Jute mallow with Finger millet and with Maize significantly increased the amount of ß-carotene in Jute mallow. Jute mallow intercropped with Sorghum (5.92 %) was not affected by intercropping on the amount of ß-carotene. Also results revealed that Jute mallow in intercropping system significantly increased the amount of crude protein and crude fibers. On the other hand, intercropping significantly decreased the amount of vitamin C in Jute mallow (Table 10). Sole Jute mallow (100.99 mg/100 g) had significantly

($p \leq 0.01$) higher levels of vitamin C than intercropped Jute mallow (ranged from 87.91 to 68.18 mg/100 g). Site-treatment interaction was significant ($p \leq 0.05$) for ß-carotene, crude protein, crude fibers and vitamin C. In Arusha, Jute mallow intercropped with Maize and with Finger millet significantly increased the amount of ß-carotene but in Dodoma, Jute mallow intercropped with Finger millet suppressed the amount of ß-carotene and crude fibers in Jute mallow leaves (Fig. 4). Crude protein and crude fibers significantly decreased when Jute mallow was intercropped with Maize in Arusha. In Dodoma Jute mallow intercropped with Finger millet increased the amount of crude protein. Vitamin C was significantly decreased with intercropping in Arusha and showed no significant difference in Dodoma (Fig. 4).

Table 10: Effect of intercropping on ß-carotene, crude protein, crude fibers and vitamin C of Jute mallow leaves

Treatments	ß-carotene (%)	Crude protein (%)	Crude fibers (%)	Vitamin C (mg/100 g)
Site				
Arusha	6.96±0.27a	23.12±0.37a	21.3±4.29a	111.43±6.42a
Dodoma	5.46±0.14b	21.83±0.42b	14.13±1.03b	52.46±6.12b
Cropping system				
Jute mallow +Maize	6.61±0.39a	22.23±0.04c	12.56±0.99c	87.91±13.73b
Jute mallow +Sorghum	5.92±0.1b	22.51±1.22b	16.63±0.83b	70.69±17.59c
Jute mallow +Finger millet	6.41±0.76a	23.13±0.25a	30.09±7.02a	68.18±8.72d
Sole Jute mallow	5.9±0.22b	22.02±0.14d	11.57±1.20d	100.99±18.01a
F statistics				
Site	219.36***	639.07***	4637.16***	95.96***
Treatment	12.34***	89.5***	6576.00***	6.57**
Site*Treatment	49.28***	790.1***	6329.71***	4.00*

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

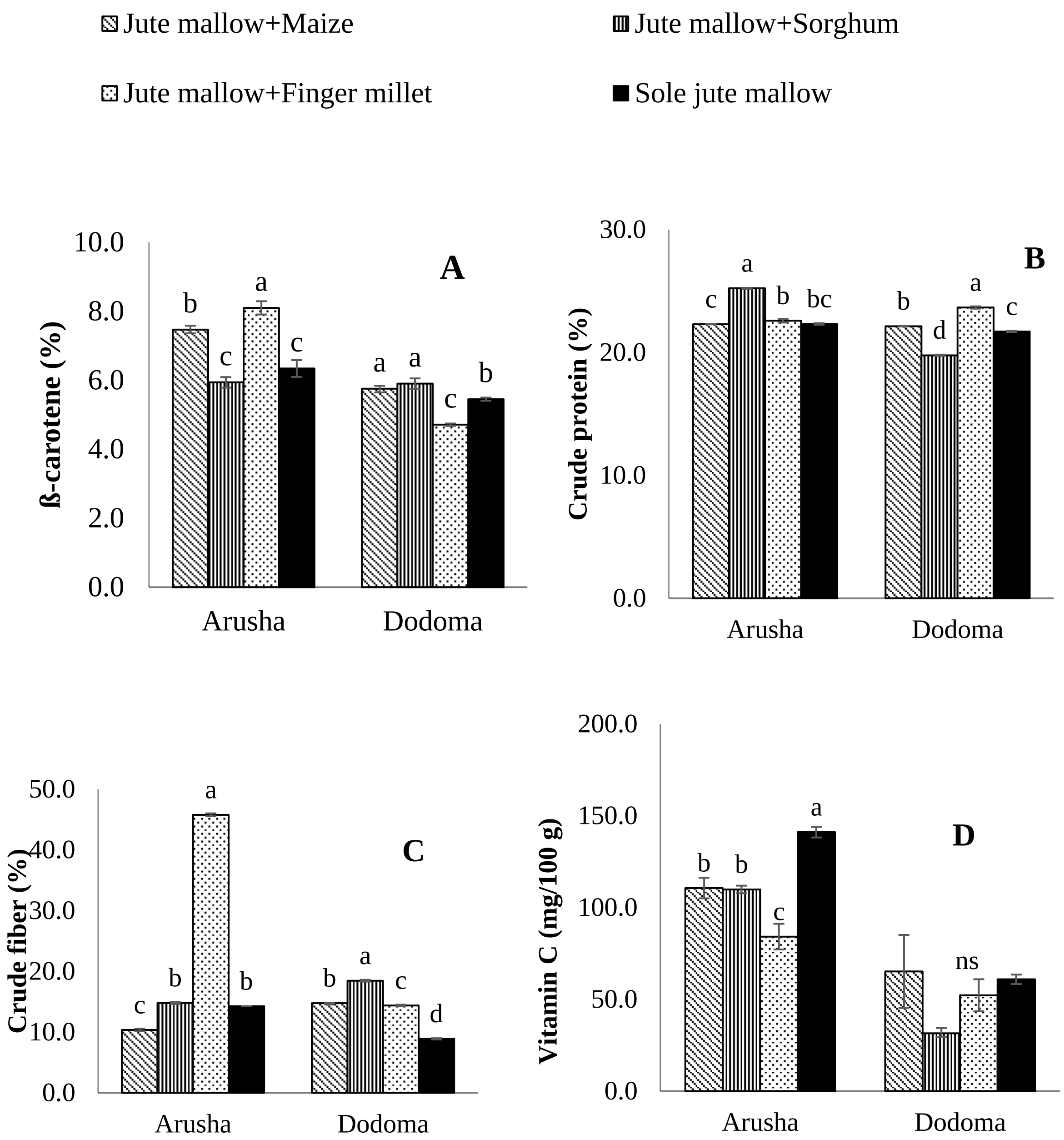


Figure 4: Site-treatment interaction of (A) ß-carotene, (B) crude protein, (C) crude fibers and (D) vitamin C levels of Jute mallow under different intercrops

4.1.8 Antinutrients of Jute mallow when intercropped with Maize, Sorghum and Finger millet

Results indicated that site effect was significant ($p \leq 0.001$) for tannins, phytate and oxalate content in Jute mallow leaves. Jute mallow grown in Dodoma had higher levels of tannins (1.12%) and phytate (4.76 mg/100 g) than Arusha while the one in Arusha had higher oxalate (3.05%) levels than Dodoma (Table 11). Treatment effect was significant ($p \leq 0.05$) for all measured antinutrients. Jute mallow intercropped with Sorghum (0.7%) and with Finger millet (0.7%) significantly decreased tannin content. Jute mallow intercropped with Maize significantly ($p \leq 0.01$) decreased the amount of phytate in Jute mallow leaves. Amount of oxalate significantly ($p \leq 0.05$) increased (2.16 to 2.6%) when Jute mallow was intercropped with Finger millet (Table 11). Site-treatment was also significant ($p \leq 0.05$) for tannin, phytate and amount of oxalate. Jute mallow with Sorghum intercrop suppressed ($p \leq 0.05$) tannin content in Arusha while intercropping did not affect tannin content in Dodoma (Fig. 5). Jute mallow with Maize intercrop significantly ($p \leq 0.01$) decreased the amount of phytate and oxalate while intercropping with Finger millet gave the highest values of the above-mentioned parameters in Arusha. In Dodoma, intercropping significantly ($p \leq 0.05$) reduced the amount of phytate and increased oxalate content when Jute mallow was intercropped with Maize and Sorghum (Fig. 5).

Table 11: Effect of intercropping on Tannins, phytate and oxalate content of Jute mallow

Treatments	Tannins (%)	Phytate (mg/100 g)	Oxalate (%)
Site			
Arusha	0.33±0.01b	3.78±0.27b	3.05±0.14a
Dodoma	1.12±0.01a	4.76±0.29a	1.66±0.06b
Cropping system			
Jute mallow +Maize	0.75±0.16a	3.63±0.10b	2.24±0.16b
Jute mallow +Sorghum	0.7±0.19b	4.52±0.22a	2.43±0.33ab
Jute mallow +Finger millet	0.7±0.17b	4.6±0.12a	2.6±0.45a
Jute mallow	0.75±0.19a	4.32±0.83a	2.16±0.35b
F statistics			
Site	3498.6***	79.27***	202.89***
Treatment	4.59*	15.00***	4.21*
Site* Treatment	4.93*	73.15***	7.28**

Values presented are means ±SE. Different letter within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test. ns=Non significant, *, **, *** = Significant at $p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.001$ respectively.

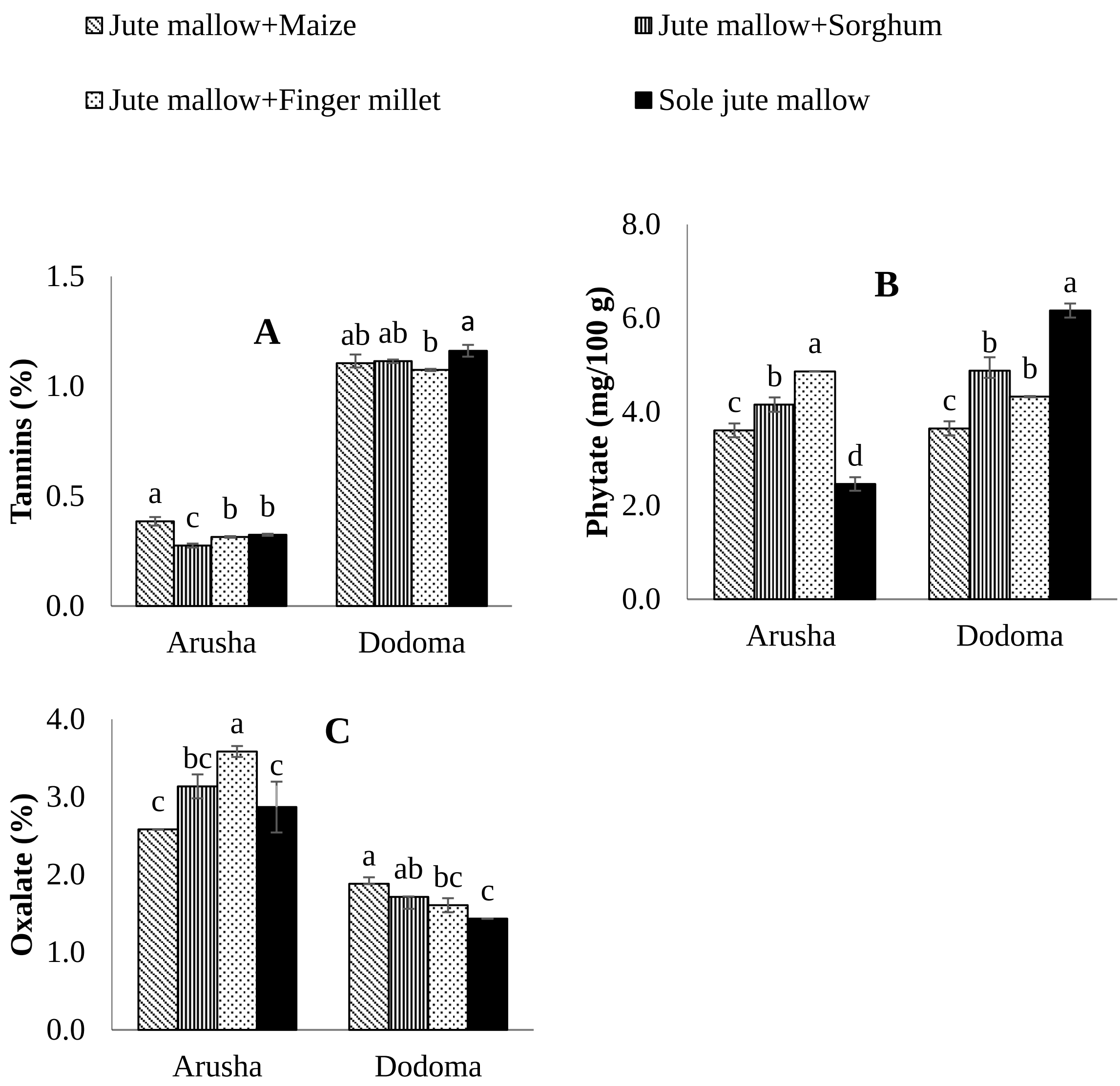


Figure 5: Site-treatment interaction of (A) Tannin, (B) Phytate and (C) Oxalate levels of Jute mallow under different intercrops

4.1.9 Nitrogen (N), Phosphorus (P) and Potassium (K) levels of intercropped Jute mallow

Site effect, treatment effect and site-treatment interaction were significant ($p \leq 0.001$) for Nitrogen (N), Phosphorus (P) and Potassium (K). N, P, K levels in Jute mallow leaves at Arusha were higher (3.7 %, 0.34 %, 3.11 %, respectively) than Dodoma (Table 12). Nitrogen and potassium levels in Jute mallow leaves were significantly ($p \leq 0.001$) increased with intercropping. Jute mallow intercropped with Sorghum did not have an effect ($p \leq 0.001$) on the level of phosphorus. However, Jute mallow intercropped with Maize (0.23 %) had a significant ($p \leq 0.001$) negative effect on the amount of phosphorus in Jute mallow leaves

(Table 12). In Arusha (Fig. 6), Jute mallow intercropped with Sorghum significantly increased levels of Nitrogen and phosphorus in Jute mallow leaves while in Dodoma, Jute mallow with Maize and Finger millet intercrops had significantly higher values of nitrogen, Jute mallow with Maize and Sorghum intercrops significantly increased the amount of phosphorus. Potassium was increased with intercropping in Arusha, while showed no significant difference in Dodoma (Fig. 6).

Table 12: Effect of intercropping on Nitrogen (N), Phosphorus(P) and Potassium (K) levels of Jute mallow

Sites/ Treatments	Nitrogen %	Phosphorus %	Potassium %
Site			
Arusha	3.7±0.06a	0.34±0.00a	3.11±0.08a
Dodoma	3.5±0.07b	0.12±0.01b	2.5±0.02b
Cropping system			
Jute mallow +Maize	3.56±0.01c	0.23±0.04c	2.95±0.19a
Jute mallow +Sorghum	3.61±0.20b	0.24±0.05a	2.83±0.17b
Jute mallow +Finger millet	3.71±0.04a	0.21±0.06d	2.85±0.15b
Jute mallow	3.53±0.02d	0.24±0.05b	2.59±0.05c
F statistics			
Site	639.07***	58881.02***	1230.75***
Treatment	89.5***	246.87***	79.55***
Site* Treatment	790.06***	308.24***	68.17***

Values presented are means ±SE. Different letter within the same column are significantly different at $p = 0.05$ as determined by Fisher’s Least Significance Difference test. ns=Non significant, *** = Significant at $p \leq 0.001$ respectively.

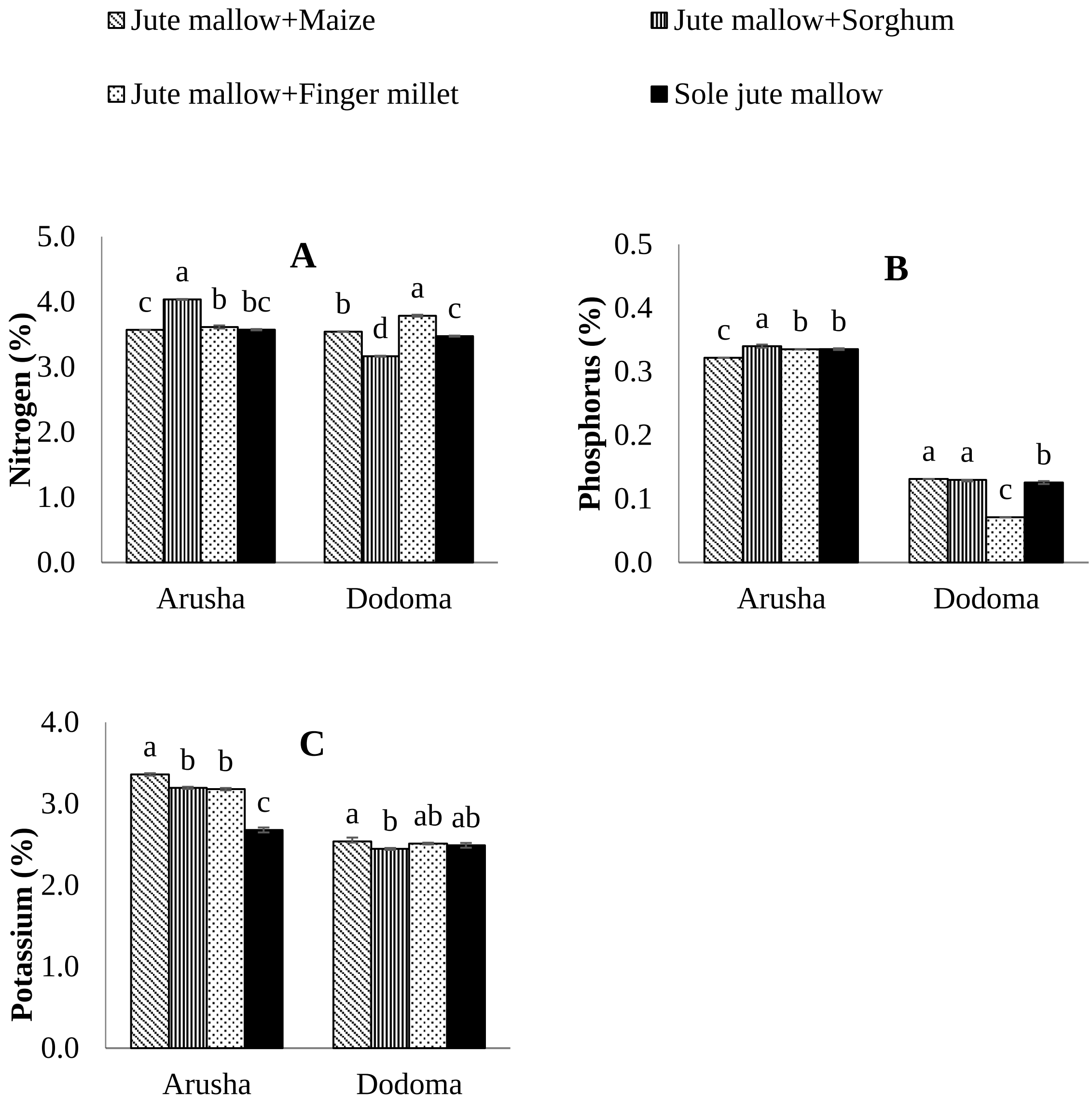


Figure 6: Site-treatment interaction of (A) Nitrogen (N), (B) Phosphorus (P) and (C) Potassium (K) levels of Jute mallow under different intercrops

4.1.10 Calcium, zinc, iron and sodium content of Jute mallow when intercropped with cereals (Maize, Sorghum and Finger millet)

Results of the study showed that site effect was significant ($p \leq 0.001$) for calcium, zinc, iron and sodium content. Arusha had higher amounts of calcium (4751.76 mg/100 g) and sodium (93.93 mg/100 g) while Dodoma had higher amounts of zinc (5.25 mg/100 g) and iron (83.89 mg/100 g) than Arusha (Table 13). Treatment effect was also found significant ($p \leq 0.001$) for calcium, zinc, iron and sodium content. Amount of calcium in Jute mallow leaves significantly increased with intercropping from 3322.63 mg/100 g to a range of 3493.92-7546.61 mg/100 g among intercropping combinations. Amount of Zinc in Jute mallow was significantly decreased when intercropped with Maize (5.7 to 3.52 mg/100 g) and with Finger millet (5.7 to 3.84 mg/100 g). Also, there was a negative effect on the amount of iron when Jute mallow was intercropped with Finger millet (62.54 mg/100 g). Amount of sodium in Jute mallow leaves (63.04 mg/100 g) significantly ($p \leq 0.001$) increased with Sorghum (118.05 mg/100 g) and Finger millet (64.70 mg/100 g) intercrops but decreased when Jute mallow was intercropped with Maize (53.93 mg/100 g) (Table 13). Furthermore, results also revealed that there was a significant ($p \leq 0.001$) interaction between site and treatment for calcium, zinc, iron and sodium content. In Arusha, Jute mallow with Sorghum and with Finger millet increased ($p \leq 0.001$) calcium and zinc content while in Dodoma, Calcium increased ($p \leq 0.001$) with Jute mallow and Maize intercrops and zinc decreased ($p \leq 0.001$) with intercropping (Fig. 7). In Arusha, intercropping decreased ($p \leq 0.001$) iron content in Jute mallow leaves while in Dodoma, amount of iron increased ($p \leq 0.001$) when Jute mallow was intercropped with Maize and with Sorghum. Amount of sodium in Jute mallow leaves where the highest ($p \leq 0.001$) when Jute mallow was intercropped with Sorghum in both sites. In Dodoma, intercropping significantly ($p \leq 0.001$) increased sodium content in Jute mallow leaves (Fig. 7).

Table 13: Effect of intercropping on calcium (Ca), zinc (Zn), iron (Fe) and sodium (Na) levels of Jute mallow leaves

Treatments	Ca (mg/100 g)	Zn (mg/100 g)	Fe (mg/100 g)	Na (mg/100 g)
Site				
Arusha	4751.76±45.39a	4.10±0.44b	54.49±1.97b	93.93±6.23a
Dodoma	4204.00±1096.17b	5.25±0.5.09a	83.89±1.82a	55.93±9.31b
Cropping system				
Jute mallow +Maize	7546.61±1321.10a	3.52±0.31c	71.14±7.61a	53.93±7.42d
Jute mallow +Sorghum	3548.38±620.55b	5.63±0.42a	71.33±8.95a	118.05±4.05a
Jute mallow +Finger millet	3493.92±611.80b	3.84±0.06b	62.54±6.72b	64.70±9.73b
Jute mallow	3322.63±578.49c	5.7±1.09a	71.75±3.04a	63.04±12.85c
F statistics				
Site	638.05***	980.84***	9799.77***	7170.27***
Treatment	8920.04***	990.51***	223.68***	4214.10***
Site* Treatment	9845.26***	1473.8***	365.93***	344.78***

Ca= Calcium, Zn= Zinc, Fe= Iron and Na= Sodium. Values presented are means ±SE. Different letter within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test. ns=Non significant, *** = Significant at $p \leq 0.001$ respectively.

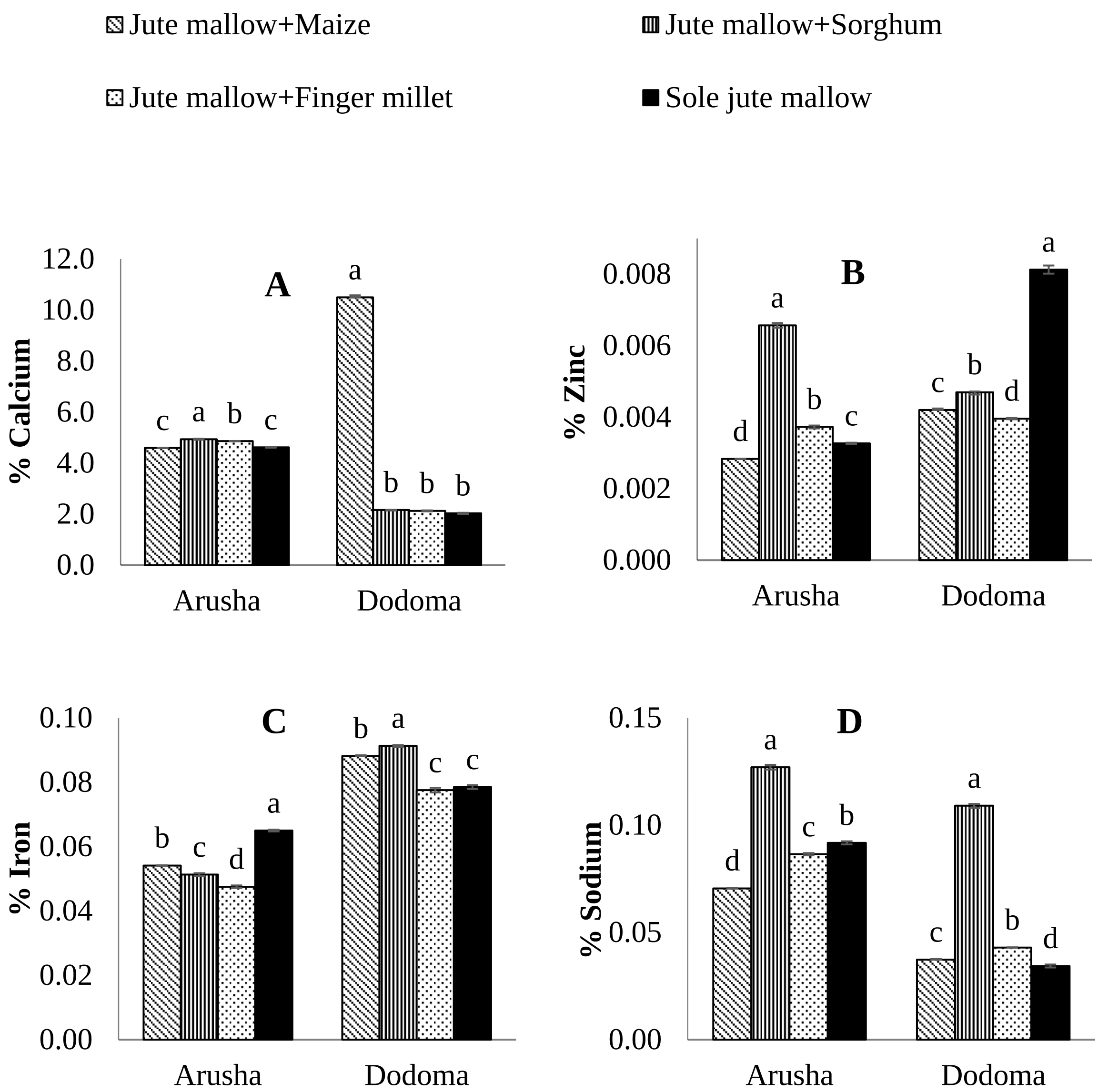


Figure 7: Site-treatment interaction of (A) calcium, (B) zinc, (C) iron and (D) sodium levels of Jute mallow under different intercrops

4.1.11 The economics of Jute mallow grown under Maize, Finger millet and Sorghum intercropping combinations

This section gives a detailed analysis on the costs and returns of Jute mallow under different cereal intercrops. The total cost of production varied with activities and inputs for each treatment at an assumption that the interest rate of money spent on buying inputs is pegged at 5%. Table 14 shows activities and inputs used to calculate the total variable cost of production.

The market selling price (USD/kg) of Jute mallow, Maize, Sorghum and Finger millet was 0.3, 0.44, 0.87 and 0.87 respectively.

Table 14: Cost of activities and inputs involved in the production process

Activities and inputs	USD
Rent	34.81
Land preparation	21.76
Planting/ha	21.76
Weeding 2 times/ha	34.81
Pesticides application	13.06
Harvesting/ha	17.41
Threshing/processing/100 kg	4.35
Irrigation	43.52
Seeds /ha	
Jute mallow	7.40
Maize	20.89
Sorghum	7.62
Millet	2.61

4.1.12 Total variable cost (TVC) and Total revenue (TR) of Jute mallow in an intercropping system

Total variable cost was the highest ($p \leq 0.001$) in Arusha relative to Dodoma for each treatment except for sole Finger millet (Table 15). In Arusha, total variable cost was the highest ($p \leq 0.001$) when Jute mallow was intercropped with Maize (806.84 USD/ha) while in Dodoma, the highest TVC was from Jute mallow with Sorghum intercrop (672.58 USD/ha). In both sites, the lowest ($p \leq 0.001$) TVC was from sole Finger millet treatment. Sole Maize treatment gave the highest revenue (4384.28 USD/ha) in Arusha since it had good yield performance than the total yield in its intercropping. In Dodoma, Jute mallow intercropped with Sorghum brought the highest revenue (3553.53 USD/ha). In both sites, the lowest revenue was from sole Finger millet treatment (Table 15).

4.1.13 Marginal net return (MNR) of Jute mallow in an intercropping system

In terms of profit obtained, Jute mallow intercropped with Sorghum gave the highest ($p \leq 0.001$) Marginal Net Return (2880.95 USD/ha) in Dodoma while Maize-Jute mallow intercrop resulted into the highest MNR (3577.44 USD/ha) in Arusha. Comparing the sites, Arusha gave higher levels of MNR than Dodoma for each treatment except sole Finger millet. Jute mallow in intercropping system resulted into significantly ($p \leq 0.001$) higher MNR levels than monocropping system of each treatment as seen in Table 15.

4.1.14 Marginal rate of return (MRR) of Jute mallow in an intercropping system

Marginal rate of return (MRR) shows how revenue has managed to cover all total variable cost of a treatment and by how many times (Table 15). Results of this study showed that Jute mallow intercropped with Sorghum (4.07), Finger millet (3.79) and with Maize (4.42) significantly ($p \leq 0.001$) increased MRR from sole Jute mallow (3.39) in Arusha. In Dodoma, Jute mallow intercropped with Sorghum brought the highest ($p \leq 0.001$) MRR (4.28). The lowest MRR was obtained from sole Finger millet treatment at 1.3 and 2.02 in Arusha and Dodoma respectively. Among intercropping combinations, Jute mallow intercropped with Finger millet resulted into the lowest MRR in both sites (Table 15).

Table 15: Total variable cost (TVC), total revenue (TR), marginal net return (MNR) and marginal rate of return (MRR) of Jute mallow intercropped with Maize, Sorghum and Finger millet

Treatment	TVC (USD/ha)	TR (USD/ha)	MNR (USD/ha)	MRR
		Arusha		
Jute mallow +Maize	806.84±29.97a	4384.28±237.10a	3577.44±207.44a	4.42±0.10a
Jute mallow +Sorghum	719.76±28.71ab	3645.62±193.54b	2925.86±164.84b	4.07±0.06b
Jute mallow +Finger millet	605.36±38.56bc	2902.61±257.24c	2297.25±218.68c	3.79±0.14d
Sole Jute mallow	676.57±49.20c	2978.32±344.42bc	2301.75±295.21c	3.39±0.20e
Sole Maize	707.88 ±37.17b	3432.84±371.73b	2724.96±334.56b	3.85±0.19c
Sole Sorghum	322.68 ±5.65d	1427.2±112.94d	1104.52±107.30d	3.42±0.31e
Sole Finger millet	278.28±1.41d	639.22±28.22e	360.94±26.81e	1.30±0.10f
Level of significance	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$
		Dodoma		
Jute mallow +Maize	603.8±19.84b	2628.61±131.51b	2024.81±111.67b	3.35±0.07b
Jute mallow +Sorghum	672.58±17.73a	3553.53±116.60a	2880.95±98.96a	4.28±0.03a
Jute mallow +Finger millet	541. 69±15.62c	2320.43±124.73c	1778.74±109.27c	3.28±0.12bc
Sole Jute mallow	641.49±9.45a	2732.72±66.12b	2091.23±56.68b	3.26±0.04bc
Sole Maize	416.09±9.09d	1514.97±90.89d	1098.88±81.80d	2.64±0.14c
Sole Sorghum	318.61±2.80e	1345.9±56.03d	1027.29±53.23d	3.22±0.16bc
Sole Finger millet	290.09±0.94e	875.52±18.74e	585.43±17.81e	2.02±0.06d
Level of significance	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$

Values presented are means ±SE. Different letter within the same column are significantly different at p = 0.05 as determined by Fisher's Least Significance Difference test.

4.2. Discussion

4.2.1 Effect of intercropping Jute mallow with Maize, Sorghum and Finger millet on growth and yield parameters of Jute mallow

Comparing sites, Dodoma had higher number of leaves and number of branches of Jute mallow relative to Arusha. Arusha had higher leaf length and leaf width than Dodoma. This may be attributed by relative low temperatures in Arusha which may have reduced the number of branches and number of leaves per plant but increased the size of the leaf. Similar findings were found in potato plants where by cooler temperatures lowered total number of branches of potato and increased leaf size (Manrique *et al*., 1989; Wolf *et al*., 1990). Another study on factors affecting number of leaves preceding the first inflorescence of Tomato also indicated that number of leaves preceding decreased with lower temperatures (Dieleman, 1992). Nordli *et al*. (2011) also found that low temperature decreases number of leaves of Hydrangea macrophylla cultivars before flowering. A study on the effect of temperature on Brassica oleracea revealed that leaves grown under control and heat environment (up to 32 ^{0}C) had larger leaves than those grown under chilling conditions (Rodríguez, Soengas, Alonso-Villaverde, Sotelo, Cartea, & Velasco, 2015).

Intercropping of Jute mallow with Sorghum and Finger millet performed significantly ($P \leq 0.05$) similar to the mono-cropped stands in plant height, number of leaves and number of branches. These attributes are known to highly contribute to the plant leaf yield. However, Jute mallow did not perform well when intercropped with Maize. Maize suppressed the growth of Jute mallow. This can be due to the shadow effect from Maize leaves, competition on nutrients and underground interactions of plants (Ndakidemi, 2006). Maluleke *et al*. (2005) and Nyoki (2017) reported a decrease in number of leaves per plant and stem girth of a legume plant respectively when intercropped with Maize. From this study, it was also found that site treatment interaction on leaf length was significant. Leaf length per plant was significantly increased with monocropping in Arusha while Dodoma showed no significant difference in leaf length. This may be caused by high fertility levels of soils in Arusha which gave good growth resources to the treatment with potential to exploit the resources well. This study further revealed that intercropping Jute mallow with Finger millet and with Maize decreased biomass yield of Jute mallow. Intercropping also delayed number of days to 50 % flowering of Jute mallow. Severe nutrients competition and low growth rate of the crops caused by high plant density in intercropping system might have caused low biomass yields and delayed flowering.

Maluleke *et al.* (2005) also reported reduced yield in Maize-lablab intercrops relative to monocrops and Moriri *et al*. (2010) reported an increase in days to 50 % flowering of cowpeas when intercropped with Maize relative to its sole stands.

Arusha had higher leaf yields (fresh and dry) than Dodoma which may be attributed by difference in fertility levels of the sites whereby Arusha had better levels of Nitrogen, Potassium and Phosphorus than Dodoma (Table 2). The study revealed that whether Jute mallow was grown in monoculture or intercropped with Finger millet and Sorghum, there was no significant difference in the plant fresh weight, fresh stem weight and fresh leaf yield obtained. However, Jute mallow with Maize intercropping reduced plant fresh weight, stem fresh weight and leaf yield of Jute mallow. Competition for light and plant nutrients might have led to reduced leaf yield of Jute mallow. Same results were reported by Rabbany (1996) whereby Jute mallow intercropped with stem amaranthus had lower yield and other yield components than mono-cropped stands. In this study, 1000 seed weight did not differ with cropping system. However, seed yield per plant was negatively affected by intercropping. Intercropping Jute mallow with Maize, Finger millet and Sorghum significantly lowered the Jute mallow seed yield per plant as compared with sole cropping. Also, there was a decrease in number of seeds per pod when Jute mallow was intercropped with Maize in Dodoma. Possible explanation could be presence of interspecific competition on plant resources which hindered seed yield development and yield attributes in intercropped stands. Katsaruware and Manyanhaire (2009) reported that interspecific competition in intercropping systems hinders better access to resources for growth and yield in intercropped plants than sole crops. Similar results were found by Emuh (2014) whereby pigeon pea intercropped with Jute mallow had lower seed yield than sole cropping system. Reduced grain yield was also recorded on soybean when it was intercropped with Maize compared with when it was in sole cropping (Nyoki, 2017).

This study also found that there was a yield advantage of intercropping Jute mallow with Maize, Sorghum and Finger millet than mono cropping with LER of 1.31, 1.53 and 1.23 for Arusha and 1.28, 1.7 and 1.22 for Dodoma respectively. This is possibly due to intercropping advantages such as reducing water evaporation and efficient utilization of nutrient resources that could have not being utilized by a single crop as described by Ghanbari *et al*. (2010). Aiyelaagbe and Jolaoso (1992) also reported that there was a yield increment and a high LER of 1.6 when Jute mallow was intercropped with papaya. Also, a study by Rabbany (1996) showed a LER greater than one when Jute mallow was intercropped with mungbean, cowpea and stem amaranthus. In this study, jute mallow and sorghum intercrop had the highest LER and the lowest LER was from jute mallow and finger millet intercrop. This means jute mallow performs better in an intercropping system with Sorghum than with Finger millet. Probably presence of tillers in Finger millet exert pressure in vegetative growth of Jute mallow unlike in intercropping system with Sorghum which grows as single plant.

4.2.2 Effect of intercropping on nutritional content of Jute mallow leaves when intercropped with commonly grown cereals

Results of this study showed that Site had a significant effect to the nutritional content of Jute mallow leaves. Arusha had higher values of ß-carotene, crude protein, crude fibers, vitamin C, Nitrogen, Phosphorus, potassium, Calcium and sodium than Dodoma. This can be attributed by high fertility status of Arusha compared with Dodoma (Table 2) Probably poor soils in Dodoma resulted to low nutritional contents in the Jute mallow leaves. Jute mallow intercropped with Finger millet had higher levels of ß-carotene, crude protein, nitrogen and crude fibers. This could be due to the fact that Finger millet has thinner leaves, so intercropped Jute mallow accessed enough light to grow well vegetatively and absorb all possible nutrients from the soil. Crop mixtures in intercropping system results to different agronomic benefits including increase in crude protein (Ibrahim *et al*., 2012). Also intercropping significantly increased the amount of Nitrogen, Potassium, Calcium and crude protein in Jute mallow, and iron content was not affected when Jute mallow was intercropped with Sorghum and with Maize. The reason behind could be interspecific facilitation between plants in an intercropping system which brought positive interactions towards these elements. The absorption of soil nutrients in jute mallow plant favoured these treatments when up taking soil nutrients which resulted to high nutritional contents in the respective Jute mallow leaves. Nyoki (2018) reported an increase in iron nutrient when soybean was intercropped with Maize compared with sole stand soybean. In another study, Maize intercropped with Mungbeans showed an increase in its crude protein as compared to the mono-cropped stands (Hamdollah, 2012). Inal *et al*. (2007) also reported increased phosphorus and potassium concentration in peanut when it was intercropped with Maize than its sole stands.

However, vitamin C of Jute mallow was significantly reduced with intercropping. This could be caused by the competition of nutrients between intercropped stands which reduced nutritional contents of Jute mallow. A study by Zhang *et al*. (2001) explained that interspecific competition between plants in an intercropping system can cause a decrease in nutrient uptake in plants. Interactive effect of site and treatment showed that intercropping negatively affected vitamin C in Arusha while having no significant effect in Dodoma. This is due to low light intensity caused by the shadow effect in intercropped Jute mallow leaves as vitamin C was reported to have a positive relationship with amount of light a plant receives. A study by Reid (1938) reported a decrease of vitamin C in cowpeas when there was low light intensity relative to good illumination conditions. Also, potassium was significantly increased with intercropping in Arusha while showing no significant difference in Dodoma. Higher soil nutrients in Arusha (Table 2) gave potential treatments ability to exploit the available nutrients.

Antinutrients reacted differently with intercropping. Tannin and phytate was found higher in Dodoma than Arusha while percentage oxalate was higher in Arusha than Dodoma. Since Dodoma had low fertility levels than Arusha (Table 2), increase of phytate and tannins content might be caused by high nutrient competition which resulted to accumulation of poisonous compounds in the plant. This can be supported by Munyaka (2010) who mentioned soil type and nutrients as one of the factors affecting amount of phytate in plants. Amounts of oxalates in Jute mallow leaves were low in Dodoma relative to Arusha. Levels of oxalates in vegetable (*Vigna unguiculate)* were reported to reduce with high temperatures (Muchoki *et al*., 2010). Dodoma is a semi-arid zone with high annual mean temperature than Arusha, so this explains as to why Dodoma had lower amounts of oxalates compared with Arusha.

4.2.3 Economic analysis of intercropped Jute mallow with Maize, Sorghum and Finger millet

Higher economic gain in intercropping system motivates farmers to easily adopt the system (Bhatti *et al.,* 2006; Nazir *et al.,* 2002). In this study, all intercropping combinations with Jute mallow brought a higher economic return than mono-cropped Jute mallow. Among the intercrops, Jute mallow intercropped with Maize and with Sorghum had significantly the highest returns to investment in both sites. Besides, the intercrop of Jute mallow with Finger millet brought the lowest economic returns when compared with other intercropping combination. Among all the treatments, lowest returns were from sole Finger millet. Even though intercropping increased the production costs per hectare, it also increased total yields, dollar profits and marginal rate of return per hectare relative to monocropping. This could be attributed by efficient use of nutrients resources (light, water, soil nutrients, space) in intercropped crops. Similar results were reported by Khatiwada (2000) who reported an increase in net returns in an intercropping system of Maize with cauliflower than their monocrops. Charles *et al*. (2011) also reported more economic gains from Finger millet with *Desmodium intortum* intercropping system than monocropping. Therefore, intercropping system is a sustainable practice which gives a farmer an opportunity to efficiently utilize a small piece of land and provide good standard of living through better economic gains relative to monocropping system.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study assessed growth, yield performance, nutritional content and economics of Jute mallow under cereal intercrops. As preference is mostly given to cereal crops, this study aimed at maximizing land use and land resources by utilizing the space between commonly grown cereals in Tanzania. The study indicated that growth parameters such as plant height, number of branches and number of leaves were not affected when Jute mallow was intercropped with Sorghum and Finger millet. While, intercropping with Maize reduced the growth and yield performance of Jute mallow. The same trend was followed in the intercropped cereals (Maize, Sorghum and Finger millet) whereby sole crop stands had higher yield than their respective intercrops. Fresh leaf yield of Jute mallow intercropped with Sorghum and Finger millet was significantly not affected by intercropping. All intercropped stands had yield advantages over mono-cropped stands with Jute mallow and Sorghum intercrops having the highest LER. Therefore, despite of the reduced individual crop yields, intercropping Jute mallow with Maize, Sorghum and Finger millet has proven to increase the total cumulative yields in an intercropping system. Jute mallow intercropped with Maize suppresses growth and yield performance of Jute mallow.

In addition, Jute mallow grown in Arusha had higher levels of ß-carotene, crude protein, crude fibers, vitamin C, Nitrogen, Phosphorus, potassium, Calcium and sodium than Dodoma. Antinutrients such as tannins and phytate were reduced when Jute mallow was grown in Arusha compared with Dodoma. The study also revealed that intercropping increases the amount of crude protein, potassium, nitrogen, and calcium in Jute mallow, and when intercropped with Maize or with Sorghum, iron levels were not affected (p = 0.05). However, intercropping suppressed vitamin C content in Jute mallow leaves. This study further supported that there is an economic gain and higher returns on investment in an intercropping system relative to monocropping system. The highest marginal rate of return in Arusha was from Jute mallow intercropped with Maize (4.76) and in Dodoma was from Jute mallow intercropped with Sorghum (4.69). Based on the above explanation, it can be deduced that Arusha favours the growth of a more nutritive Jute mallow as compared to Dodoma. Jute mallow intercropped with Sorghum, Maize and Finger millet gives more economic returns than their respective sole stands.

5.2 Recommendations

In summary, to maximizing land use and land resources, this study recommends Jute mallow to be intercropped with Sorghum in Dodoma and with Maize in Arusha for better yields, sustainable growth and higher returns. Farmers should use the results generated by this study to make proper cultivating arrangements by including Jute mallow in their farming plan.

However, future research can focus on the following:

- Altering planting spacing of Jute mallow and cereals in intercropping combinations to see if there is more possibility of optimizing land in specified locations of this study.
- Comparing the performance of different accessions of Jute mallow in different cropping systems.
- Relationship between intercropping system and nutritional contents of respective crops and whether fertilizer application may alter the performance in growth, yield and nutritional content.
- The effect of intercropping system in nutrients uptake of Jute mallow, Maize, Sorghum and Finger millet.
- Comparing yield, nutrient uptake and nutritional content Jute mallow with other African indigenous vegetables (Amaranth, African eggplant, African nightshade, etc.) in different cropping systems.

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APPENDICES

Appendix 1. Plant growth data on Jute mallow intercropped with cereals (Maize, Sorghum and Finger millet) at six weeks after planting

Site	Treatment	Height (cm)	No. of branches	No. of leaves	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Canopy (cm)
Arusha	Jute mallow +Maize	48.1 ± 1.90	5.45 ± 0.23	62.62 ± 0.99	0.55 ± 0.01	6.97 ± 0.28	3.45 ± 0.10	22.46 ± 0.92
Arusha	Jute mallow +Sorghum	70 ± 3.70	7.42 ± 0.42	77.5 ± 3.25	0.55 ± 0.01	7.44 ± 0.32	3.59 ± 0.10	29.04 ± 0.98
Arusha	Jute mallow +Finger millet	72.07 ± 2.15	7.39 ± 0.36	77.89 ± 1.80	0.54 ± 0.01	7.73 ± 0.23	3.44 ± 0.08	28.01 ± 0.80
Arusha	Jute mallow	76.32 ± 2.78	7.84 ± 0.21	82.89 ± 2.43	0.64 ± 0.03	8.87 ± 0.09	3.41 ± 0.05	25.88 ± 0.80
Dodoma	Jute mallow +Maize	41.08 ± 1.94	5.7 ± 0.44	59.34 ± 2.10	0.55 ± 0.03	6.75 ± 0.34	2.29 ± 0.08	26.42 ± 1.64
Dodoma	Jute mallow +Sorghum	68.84 ± 4.05	8.84 ± 0.95	86 ± 7.44	0.56 ± 0.04	7.2 ± 0.45	2.82 ± 0.21	27.32 ± 1.82
Dodoma	Jute mallow +Finger millet	69.05 ± 4.82	9.78 ± 0.70	93.91 ± 4.26	0.62 ± 0.04	6.94 ± 0.20	2.51 ± 0.05	27.47 ± 1.14
Dodoma	Jute mallow	71.07 ± 4.89	9.67 ± 0.60	88.73 ± 7.07	0.64 ± 0.02	6.66 ± 0.39	2.27 ± 0.09	26.11 ± 0.66

Appendix 2. Data on Moisture content and Biomass yield of Jute mallow under Maize, Sorghum and Finger millet intercrops

Site	Treatment	Biomass yield per plant (g)	Moisture content (%)
Arusha	Jute mallow +Maize	36.86±2.89	57.5±2.40
Arusha	Jute mallow +Sorghum	50.22±6.63	52.19±5.96
Arusha	Jute mallow +Finger millet	37.33±4.25	63.62±6.30
Arusha	Jute mallow	47.19±4.96	57.41±2.24
	Intercrop mean	41.47±4.59	57.77±4.89
Dodoma	Jute mallow +Maize	27.77±5.00	58.43±5.59
Dodoma	Jute mallow +Sorghum	38.57±1.66	54.21±2.15
Dodoma	Jute mallow +Finger millet	30.33±2.55	60.31±1.09
Dodoma	Jute mallow	43.13±0.69	52.49±1.29
	Intercrop mean	32.22±3.07	57.65±2.94

Appendix 3. Data on days to 50 % flowering of Jute mallow and cereals (Maize, Sorghum and Finger millet) in an intercropping system

Site	Treatment	Jute mallow	Respective intercrop	Cereal
Arusha	Jute mallow +Maize	59.84 ± 1.11	71±1.39	Intercropped Maize
Arusha	Jute mallow +Sorghum	56.17 ± 0.70	67.34±0.49	Intercropped Sorghum
Arusha	Jute mallow +Finger millet	55.67 ± 0.49	71±0.63	Intercropped Millet
Arusha	Jute mallow	53.5 ± 0.72	-	
Arusha	Maize	-	67.84±1.45	Sole Maize
Arusha	Sorghum	-	63.67±0.88	Sole Sorghum
Arusha	Millet	-	67.5±1.06	Sole Millet
Arusha	Intercrop mean	57.23±0.77		
Dodoma	Jute mallow +Maize	59.67±0.99	70.67±1.23	Intercropped Maize
Dodoma	Jute mallow +Sorghum	56±0.63	67.17±0.48	Intercropped Sorghum
Dodoma	Jute mallow +Finger millet	55.67±0.49	71±0.45	Intercropped Millet
Dodoma	Jute mallow	53.5±0.67	-	
Dodoma	Maize	-	68±1.51	Sole Maize
Dodoma	Sorghum	-	63.5±0.81	Sole Sorghum
Dodoma	Millet	-	67.17±0.91	Sole Millet
Dodoma	Intercrop mean	57.12±0.71		

Appendix 4. Data on plant leaf yield of Jute mallow when intercropped with Maize, Sorghum and Finger millet

Site	Treatment	plant fresh weight (g)	Fresh stem weight (g)	Fresh leaf weight per plant (g)	Dry leaf weight per plant (g)
Arusha	Jute mallow +Maize	86.88 ± 4.82	50.11 ± 2.24	34.82 ± 1.83	14.78 ± 1.10
Arusha	Jute mallow +Sorghum	105.38 ± 7.48	62.52 ± 6.00	43.28 ± 4.61	19.71 ± 1.35
Arusha	Jute mallow + Finger millet	107.71 ± 6.36	60.81 ± 4.35	45.09 ± 2.66	15.67 ± 1.82
Arusha	Jute mallow	110.3 ± 9.06	61.55 ± 5.34	45.58 ± 4.15	19.56 ± 2.26
	Intercropping mean	99.99 ± 6.22	57.81 ± 4.20	41.06 ± 3.03	16.72 ± 1.42
Dodoma	Jute mallow +Maize	64.71 ± 4.22	37.04 ± 4.72	26.14 ± 1.63	10.57 ± 1.03
Dodoma	Jute mallow +Sorghum	84.59 ± 3.05	47.04 ± 1.95	36.57 ± 1.30	16.7 ± 0.84
Dodoma	Jute mallow +Finger millet	76.17 ± 5.60	44.38 ± 4.44	30.69 ± 1.65	12.16 ± 0.67
Dodoma	Jute mallow	91.02 ± 2.22	51.86 ± 1.10	37.92 ± 1.43	17.95 ± 0.43
	Intercropping mean	75.16 ± 4.29	42.82 ± 3.70	31.13 ± 1.53	13.15 ± 0.85

Appendix 5. Data on seed yield of Jute mallow when intercropped with Maize, Sorghum and Finger millet

Site	Treatment	No. Pods per plant	Pod length	No. Seeds per pod	1000 Seed weight	Seed yield per plant(g)
Arusha	Jute mallow +Maize	14.67 ± 0.42	5.71 ± 0.04	147.54 ± 1.19	2.43 ± 0.13	5.26 ± 0.30
Arusha	Jute mallow +Sorghum	15.84 ± 0.87	5.81 ± 0.16	143.07 ± 6.35	2.35 ± 0.13	5.39 ± 0.66
Arusha	Jute mallow +Finger millet	14.12 ± 0.59	5.38 ± 0.19	136.17 ± 9.63	2.04 ± 0.12	3.88 ± 0.30
Arusha	Jute mallow	17.12 ± 1.22	5.94 ± 0.08	151.51 ± 6.44	2.59 ± 0.10	6.65 ± 0.47
	Intercropping mean	14.88 ± 0.63	5.63 ± 0.13	142.26 ± 5.73	2.27 ± 0.13	4.84 ± 0.42
Dodoma	Jute mallow +Maize	12.34 ± 0.80	5.95 ± 0.12	138.51 ± 6.61	2.21 ± 0.12	3.76 ± 0.33
Dodoma	Jute mallow +Sorghum	13.5 ± 0.62	6.85 ± 0.21	166.39 ± 2.36	1.94 ± 0.10	4.34 ± 0.29
Dodoma	Jute mallow +Finger millet	14.89 ± 0.54	6.11 ± 0.23	170.89 ± 1.47	2.33 ± 0.09	5.92 ± 0.31
Dodoma	Jute mallow	14.33 ± 0.58	6.63 ± 0.09	171.68 ± 2.50	1.96 ± 0.10	4.78 ± 0.18
	Intercropping mean	13.58 ± 0.65	6.3 ± 0.19	158.6 ± 3.48	2.16 ± 0.11	4.67 ± 0.31

Appendix 6. Yield and yield attributes of Maize when intercropped with Jute mallow

Treatment	Height at harvest (cm)	Cob per plant	Cob weight per plant (g)	No. Seeds per cob	Seed weight per cob	1000 seed weight	Yield per plant
		Arusha					
Jute mallow +Maize	129.39 ± 3.39	1 ± 0.00	43.93 ± 3.44	378.83 ± 6.44	110.36 ± 6.92	286.17 ± 11.42	110.36 ± 6.92
Maize	188.84 ± 4.89	1.4 ± 0.13	56.15 ± 4.45	422.34 ± 11.77	164.73 ± 7.21	388.5 ± 7.46	229.2 ± 19.22
		Dodoma					
Jute mallow +Maize	123.1 ± 3.34	1 ± 0.00	30 ± 1.76	256.79 ± 13.46	52.73 ± 1.32	199.23 ± 6.26	52.73 ± 1.32
Maize	146.11 ± 6.47	1.07 ± 0.04	37.09 ± 1.12	279.13 ± 4.83	73.2 ± 1.77	266.07 ± 5.58	78.33 ± 4.70

Appendix 7. Yield and yield attributes of Sorghum when intercropped with Jute mallow

Site	Treatment	Height at harvest	Length of panicle at harvest	Av. panicle weight	1000 seed weight	Yield per plant
Arusha	Jute mallow +Sorghum	110.63 ± 4.83	19.29 ± 0.49	24.76 ± 0.25	2.84 ± 0.13	16.64 ± 0.36
Arusha	Sorghum	122.08 ± 1.50	26.05 ± 0.50	56.61 ± 4.02	3.64 ± 0.11	36.9 ± 2.92
Dodoma	Jute mallow +Sorghum	95.13 ± 2.32	16.2 ± 0.46	39.5 ± 1.17	3.35 ± 0.09	26.11 ± 0.55
Dodoma	Sorghum	102.32 ± 1.43	19.98 ± 1.10	51.46 ± 1.08	4.1 ± 0.06	34.8 ± 1.45

Appendix 8. Yield and yield attributes of Finger millet when intercropped with Jute mallow

Site	Treatment	Height at harvest	Tillers per plant	Fingers per plant	Plant panicle weight (g)	Seed weight per panicle	1000 seed weight	Seed yield per plant (g)
Arusha	Jute mallow +Finger millet	64.25 ± 1.24	3.84 ± 0.38	4.53 ± 0.24	3.09 ± 0.13	1.47 ± 0.05	3 ± 0.16	5.62 ± 0.54
Arusha	Finger millet	72.09 ± 0.64	5.67 ± 0.19	5.83 ± 0.10	5.43 ± 0.17	2.92 ± 0.05	3.8 ± 0.06	16.53 ± 0.73
Dodoma	Jute mallow +Finger millet	66.79 ± 0.46	3.94 ± 0.29	4.54 ± 0.25	4.51 ± 0.15	3.09 ± 0.06	3.24 ± 0.12	12.12 ± 0.89
Dodoma	Finger millet	73.39 ± 0.56	5.69 ± 0.14	5.67 ± 0.24	5.41 ± 0.19	3.99 ± 0.05	4.24 ± 0.09	22.64 ± 0.48