The influence of recommended agronomic practices irrigation supplementation, and compost FYM fertilization on growth, productivity and cassava yield response in Mara and Coast regions.

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Abstract: Throughout the tropics and subtropics cassava is grown on a wide range of soils, the main limitation being that the soi1has to be reasonably well drained Howeler, (2021). Cassava is important for both small-scale farmers and larger-scale plantations due to its low requirement for nutrients, ability to tolerate dry conditions and easy low-cost propagation. The crops' ability to tolerate drought and grow on poor marginal soils makes it a good crop for food security and also these characteristics are highly valuable in the face of climate variability (Awa and Tumanteh, 2001). The crop is not capital intensive as it requires minimal care and supervision, thus, it is generally still cultivated by small scale farmers as a subsistence crop in a diverse range of agricultural and food systems El-Sharkawy, (2003). Field experiments were conducted for two seasons and single season 2021/2022 and 2022/2023 under rainfed condition as a control and irrigation supplementation in the subsequent cropping season to determine the influence of agronomic practices compost FYM + Fertilizers + Irrigation supplementation on growth, productivity and yield performance. The experiments were laid out in a RCBD design with three (3) blocks and four (4) replications in different location sites. The study took place in Mara and Coastal regions, at Nyasirori Butiama district and Nyegina and Busungu-Majita Musoma rural district and Msoga Bagamoyo Coast region between October, 2021 and August, 2023. At each location site eight (8) cassava varieties and eight (8) agronomic practice treatments were tested among them involved compost FYM + Fertilizers + Irrigation supplementation separately at three different application rates 100 kg, 60, kg and 20 kg per row. Incorporated with the soil prior planting of cassava seed materials, similarly the irrigation supplementation was done also with three different regimes; the control as rainfed, irrigation supplementation up to vegetative of stage five (5) months and irrigation supplementation up to maturity stage of nine (9) months. Data on cassava growth, productivity and yield performance such as plant height (PH), plant canopy (PC) number of branches (NBR), leaf area size shape and abnormality (LSSA), crop performance (CP) and cassava root yield (RYID) and vegetative yield (VEGYID) were collected for assessment of cassava growth and productivity performance and data on number of tubers per plant, weight of cassava root fresh (RYID) and stem vegetative weight biomass was recorded for assessment of cassava yields. The results found that there was significant influence of agronomic practice treatment particularly the application of compost FYM + solely or in combination with irrigation supplementation. Likewise, the growth stage and variety effects similarly, showed significantly different at $P < 0.001$ level of significance. However, Kipusa and Mkuranga 1 varieties showed the highest mean height among the 8 varieties assessed in this experimental field research, while Chereko and Rwabhakanga showed the lowest means. Thus, conversely confirmed their influence of increasing growth and productivity parameters such as plant height (PH), plant canopy (PC), NBR, LSSA, CP, root yield (RYID) and vegetative yield (VEGY) in the two successive cropping seasons of 2021/2022 and 2022/2023 and single cropping season at Msoga Coastal and (Nyasirori, Majita and Nyegina villages of Mara location sites) respectively. Generally, significant and higher mean for plant height were recorded with Irrigation+FYM+Crop rotation, followed by Mono+FYM+ Irrigation and Crop Rotation treatments with similar growth height effect at (P< 0.001). However, the Coast region had the highest growth performance for PH and PC than the Mara region with Msoga village location having the highest means followed by Nyasirori while Nyegina and Busungu-Majita showing the smallest means performance among the 4 village location sites. The agronomic treatment application of Compost FYM + Fertilizers with or without irrigation supplementation either in monocropping or crop rotation significantly at P < 0.001 level of significance not only improve cassava growth, productivity and yield response they have a spillover effect of improving soil texture and characteristics particularly to poor soils and sand one, with an added advantage of increasing water holding capacity (moisture) and regulating soil temperature for better crop growth and performance with longer shelf life thus resilient and sustainable. However, the best results and recommended application rates of compost FYM were found to be ranging between 40 and 60 kg per row equivalent to 20.0-32.0 t ha-1 application rates depending on soils type (i.e., too poor and too sandy or sandy-sandy loam) and fertility status of the soil.

Keywords: Compost-FYM, Biofertilizers, Cassava (*Manihot esculenta* Crantz), Irrigation supplementation, cropping systems, Planting dates, Monocropping, Crop rotation

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1. Introduction

Cassava (*Manihot esculenta Crantz*) a perennial shrub crop of the family Euphorbiaceae, cultivated mainly for its starch tuberous roots. The crop plant is a shrub reaching 1-4 m or 2-5 m height and can be pluriannual, annual or biennial (Veltkamp 1985; Alves 2002; Msogoya 2006; Rosario-Arellano 2020; S. Yabuta 2021; Fayisa 2021) depending on varieties and the management practices. Which have been adapted for long stay or storage underground, thus can be freshly retrieved from the soil up to three years after maturity (Lebot, V. 2009). Although it is rich in starch, cassava ranks the third and fourth most important source of energy (carbohydrate food source) in the tropics and for the Sub-Saharan Africa after wheat, rice and maize, and providing more than 60% of the daily caloric needs to more than 800 million people in the tropics FAO (1999); Alfredo et al. (2000); Prakash (2001); FAO (2002); El-Sharkawy (2003); FAO (2010); Jan (2017); CIAT (2018); and J Ouma (2019); and the sixth most important food crop after sugar cane, maize, rice, wheat and potato, in terms of global annual production (FAO. 2002; El-Sharkawy. 2003; and FAOSTAT 2010).

It is regarded as a subsistence staple food crop and as a food security source against famine. It is also regarded as the most competitive crop used as food and raw materials for production of starch, animal feed, alcohol, cloth, pastry and thickening agent in the food industry DL Dufour (1996); Balagopalan (2002); Oguntunde (2005). Cassava is a major part of the diet for over 800 million people in approximately 80 countries (Balagopalan, 1998; FAO 2000; Lebot, V. 2009). Mostly in Sub-Saharan Africa, but also in other parts of Africa, Asia, the Pacific and South America. Cassava is important for both small-scale farmers and larger-scale plantations due to its low requirement for nutrients, ability to tolerate dry conditions and easy low-cost propagation. It can grow on poor soils, is easily propagated, requires little cultivation, and can tolerate periodic and extended periods of drought (Hillocks, R.J.; Thresh, J.M.; Bellotti, A.C 2002; El-Sharkawy 2003; De Tafur, S.M.; El-Sharkawy, M.A.; Cadavid, L.F 1997; Dahniya, 1994). The crops' ability to tolerate drought and grow on poor marginal soils makes it a good crop for food security and also these characteristics are highly valuable in the face of climate variability (Awa and Tumanteh, 2001).

The crop is not capital intensive as it requires minimal care and supervision, thus, it is generally still cultivated by small scale farmers as a subsistence crop in a diverse range of agricultural and food systems El-Sharkawy, (2003). Under optimal environmental conditions, it compares favorably in production of energy with most other major staple food crops due to its high yield potential. Moreover, cassava is not dependent on fertile soils and it will produce at least some crop yield, even in very unfavorable weather conditions where it can play a key role in food security. And about sixty to seventy percent of cassava produced globally is used for food (FAO 2000; El-Sharkawy, 2003). The greatest per capita consumption of this crop is in sub-Saharan Africa (up to 800 g per person per day), where it is the main source of energy for over 40% of the population (FAO 2000; Nhassico et al., 2008). Consumption of cassava is also high in South America and parts of the South Pacific. Worldwide, production of this crop has doubled in the past 30 years from 118 million to 233 million tonnes (FAOSTAT 2010), with most of that increase on small-scale subsistence farms in Africa (Nhassico et al 2008; Hillocks 2002). They can be eaten as chips (fried or boiled) but more commonly they are processed into some kind of flour or granular product, such as tapioca, farinha or gari (Balagopalan, 2002). The type of processing depends on the cultivar, the food storage requirements and cultural traditions (Lebot, V. 2009; FAO 2000; Montagnac, 2009; Balagopalan, 1998). In many regions the leaves are also consumed, both fresh and cooked (Lebot, V. 2009; Achidi et al 2005). Although the leaves typically have higher concentrations of protein, minerals and vitamins than the tubers, the vitamins can be destroyed during cooking (Montagnac, 2009). Leaves and tubers are also used as animal feed (Balagopalan, 2002). Agriculture in Tanzania plays a very important role in her economy, particularly in rural areas about 70% of people are engaged in agriculture and 20% to 30% of the remaining population are engaged/employed in agribusiness activities such as transportation, distribution, processing, selling and marketing. In the country smallholder farmers dominate the agricultural sector with average farm sizes of between 0.2 and 2.0 hectares, depending on the location URT (2015). It generates 25 percent of the GDP and contributes 30 percent of export earnings. Of this amount, livestock production contributes nearly 5% and fishery slightly more than 1%. The sector offers livelihoods to over 80 percent of the population and employs 75 percent of the total labor force URT (2016), Wenban-Smith et al. (2016); Cochrane and D'souza (2015). Agriculture production is vital and regarded as the Man's mainstay globally, as recent global food demand estimates show that food production will need to double by 2050 (Baulcombe, et al. 2009). This is justified by the fact that, most of the world's population, man and animals are chiefly relies and dependent on a plant-based diet. However, it is further estimated that more than 50% of the people living in Sub-Saharan Africa are employed in agriculture ILO-(2015). Whereas, in the country (Tanzania) in particular the sector offers livelihoods to over 80 percent of the population and employs 75 percent of the total labor force URT (2016), Wenban-Smith et al. (2016); Cochrane and D'souza (2015). Therefore, as a result, over the past two decades, poverty has remained high, particularly in Sub-Saharan Africa (about 30% of the total population) ILO-(2015). Whereas, in the entire period, the share of people living on less than USD 1 a day in this region still exceeded that found in the poorest region of South Asia by about 17%.

Cassava including the other species of the genus Manihot are believed to be a native and origin from South America originated from two centers of diversity, namely the North-South America, North-Eastern Brazil and Paraguay, and the second being Southern and Western parts of Mexico Alves (2002). The Crop was introduced into Sub-Sahara Africa at the end of 16th Century. And later it started to spread rapidly mainly into West Africa, Central Africa and from where it penetrated further inland via the basin of the River Congo. In Eastern Africa, the dissemination of Cassava came later, at the end of the 17th Century R.J. Hillocks, J.M. Thresh and Anthony Bellotti (2002); Olwuagwu (2012); A. De Bruyn (2012); J. Legg (2014); F. Guira (2017); R.J. Hillocks (1998), Where, it was introduced via the islands of Reunion, Madagascar and Zanzibar. The world largest producer countries of Cassava are Nigeria, which is the major producer for about 52 million tons of Cassava annually; followed by Thailand about 30 million tons of cassava, Zaire (now Congo DRC) and Indonesia J.H Cock (1985); F. Nweke (2004); A. Burns (2010); FAO (2019). Production in Africa and Asia continues to increase, while that in Latin America has remained relatively level over the past 30 years, Alves (2002). Other producing countries include Brazil, Indonesia, Vietnam, and Costa Rica. Whereas, Thailand has remained the main exporter of cassava with most of it going to Europe, FAO, (2002), Alves (2002). Thus, it is therefore regarded as a prominent industrial crop in Asia and Latin America, and widely grown staple crops in Sub-Saharan Africa with a total world production of 280 million tons with more than 90 million tons, for Sub-Sahara Africa which is about 32% of the global cassava production, (FAO 2001; 2011; 2012). This justifies the importance and potentiality of the crop for the export market following the vast industrial and commercial application in Asia and Europe, from the Sub-Saharan African countries compared to Asia and Latin America.

The major cassava growing area in Tanzania is the Lake Zone, followed by Southern and Eastern zone, as well as other regions such as Kigoma, Ruvuma, and Central zone R.E Kapinga (1995); Kilimo (2020); TZNY. (2012); and Baba Sani (2018). Whereas the Lake Zone in Tanzania still is the leading cassava producing zone that accounts for about 37.43% of the total cassava in the country, followed by the Southern zone, 26.50%; the Eastern zone, 12.36%; while other five zones produce only 24.15% of the cassava root yield in the country (TZNY. 2012; Baba Sani 2018). However, the current cassava production and productivity in Tanzania trend stands around 5.58 million tons, with an average productivity of only 5.5 tons per hectare S. Hauser (2014); TIC (2019); Agri-census (2019-20), F.F Masisila (2020); Kilimo (2020). This is 9.9 times lower compared to the potential yield of 50 tons per hectare TIC (2021), and makes Tanzania to rank the 11th cassava producer, world-widely, and the 6th largest in Africa after Nigeria (top producer in the world), Ghana, DRC, Angola and Mozambique. The low productivity and yield of cassava is attributed to compounded effect of the use of low yielding landrace cultivars, which are also susceptibility against major cassava's biotic stress – diseases and insect pests as well as abiotic factor exacerbated by climate change and weather variability E. Okogbenin (2013); S. Macfadyen (2018); D. Boansi (2017); A. Raza (2019); S. Skendzic (2021); S.K Muiruri (2021); V. Alonso Chavez (2021). Therefore, increasing agricultural intensification and productivity is critical to meeting the continued rising demand for food worldwide and Tanzania in particular. The increased agricultural intervention, innovation and intensification technologies are particularly important and play immense role in increasing food productivity in Tanzania. These Agricultural technologies are said to include all kinds of improved techniques and practices which affect the growth of agricultural output (Jain, Arora, and Raju, 2009). Thus, changes in technology are essential for agricultural productivity, food security, and poverty alleviation in developing countries, particularly in Sub-Saharan Africa (Mwaura, 2014). Moreover, it is common knowledge that smallholder farmers can benefit from the improved crop seed varieties and corresponding farming practices (Osewe et al., 2020) and their embedded new technology.

Thus, cassava is an important means by which food production could be increased without the use of large amounts of agricultural inputs (such as fertilizers, water and pesticides). Cassava is also emerging as an important large-scale agricultural crop for use as a bio-fuel (De Vries et al. 2010) and a source of industrial starch (Lebot, V. 2009; FAO 2000; Balagopalan 2002). It is sometimes referred to as the "drought, war and famine crop of the developing world" and reliance upon this crop is expected to increase in the coming years as the global climate changes. Therefore, Cassava has the potential to improve food security and livelihoods of the resource-poor rural farmers, processors, and their families (Suárez et al., 2017; Muchira, 2019; Mokhtar, 2020). Thus, therefore mitigating the challenge of cassava planting materials would contribute to increasing land under cassava and hopefully cassava productivity (Mwang'ombe et al., 2013; Shirima et al., 2019) and consequently the prevention, management and control of the cassava viral diseases in the pandemic areas notably Mara and Coast regions. Nonetheless, the rate of adoption of some improved cassava varieties is still very low, mostly especially in locations where certain abiotic and biotic stresses are severe (Alene et al., 2013; Alou et al., 2014; Afolami et al., 2015; Bechoff et al., 2018; Nakabonge et al., 2018). Moreover, in the country (Tanzania) similar studies, were conducted in various region to determine the factors limiting production of various crops including cassava; whereas, lack of improved cassava seed varieties and agricultural technologies were dominant (Bandira and Rasul, 2002, 2006; Mwangi and Kariuki, 2015; Abady et al. (2016); Mukiibi et al., 2019; Shirima et al., 2019).

2. Methodology

2.1 Research Materials

The research planting materials were four (4) improved or resistant varieties from TARI-Kibaha, namely; (Mkuranga 1 (Mk) and Kipusa (Kp), Chereko (Ck) and Kiroba (Kb) from TARI-Kibaha) and also four (4) susceptible vars. Two (2) of which will be local vars namely; Kirati var and Rwabhakanga Var (Rb) from Mara region and lastly two (2) local vars from Pwani region namely Kigori maziwa Var *(*Km), Rasta *or* Nachiyaya Var (Rn). However, these varieties were tested for CMV and CBSV resistant genes before utilization or execution of research activities under field condition, for resistant or susceptibility genes in their respective varieties. Compost manure and Fertilizer Unique (NPK17:17:17 and Nitrabor CAN 26:15.4:0.3 B) were bought from commercial Agro-input dealer shops. Prior to planting, the planting materials were disinfected in 70% alcohol and rinsed with warm water.

2.2 Research Design and Methods

2.2.1 Experimental Study Location Research Sites and Duration

A rainfed field experiment with agronomic treatments application supplemented with irrigation regimes was conducted between November, 2021 to August 2023 at two agroecological zones sites. The study covered two of the Agro-ecological Zones of the country (the Lake Zone Mara-Region and the Coastal Zone Pwani-Region), where cassava is being cultivated more intensively. The former intervention districts where cassava is still regarded as an important staple food crop but with serious limitations of soil fertility and severe disease incidence particularly CMD and CBSD than the later. The research field's location sites were located in the four (4) sites, namely; - Nyasilori, Nyegina and Busungu-Majita stations in Mara and at Msoga station in Chalinze-Coast region. Laboratory research experiments were conducted in the Department of Molecular Biology and Biotechnology MBB-CoNAS at the University Dar es Salaam in collaboration with Inqaba Biotech East Africa Ltd-Tanzania.

2.2.2 Treatments, Materials and Experimental set up

2.2.2.1 Treatments, Experimental Design and layout

Eight treatments were tested in a completely randomized block design (CRBD). However, it was assumed that N was the most limiting nutrient for cassava growth followed by P and then K for cassava root yield and productivity and also for disease control, prevention and management. The fertilizers materials (FYM-compost and Fertilizers Unique NPK 17:17:17 and Nitrabor CAN 26:15.4:0.3 B) compounded as the source of macronutrient N P K and micronutrient S, Zn, Mg and B. The fertilizer materials were applied as compound in combination and with a uniform application per respective treatments with or at an application rate of 20 kg, 60 kg, and 100 kg per row for each 8 rows per plot in each respective FYM-compost and fertilizer treatments for each respective block. A piece of land equivalent to (0.5 acres) per site or replication, including the 1.2 m passage after each main plot were used, in which eight (8) plots were laid out, each with 60.5 m^2 plot size and a 0.65 m^2 varietal plot size within. The FYM-compost and Fertilizer's materials compounded as a treatment were used to determine if application could increase cassava productivity, yield and also if it could reduce and control, manage and prevent the incidence and severity of cassava viral diseases CMD and CBSD in the study location. The fertilizer nutrient sources were FYM-Compost, Yara Unique NPK 17:17:17 and Yara Nitrabor (CAN 26:15.4:0.3). The fertilizers materials were applied in splits firstly, as a compound fertilizer with FYM-Compost before planting per row per plot and the second application splits involving the same (NPK and CAN only) were applied just about two months after planting at points about 15 cm away from the planted stem. The popular improved and resistant cassava varieties Mkuranga 1, Kipusa, Kiroba, and Chereko were selected and used as disease tolerance or resistance varieties available in Tanzania. And local susceptible varieties such as Kigori maziwa, Rasta, Rwabhakanga and Kirati were used and tested as susceptible and infected cassava varieties. Whereas in total eight different cassava varieties (4 resistant and 4 susceptible) were randomly assigned to the eight (8) treatments; compost manure supplemented with inorganic fertilizer application at the rate of (100 kg, 60 kg and 20 kg) per plot, different planting dates, (October-November, February-March and in April-May), different cropping systems (continuous mono cropping, intercropping with cover crops, crop rotation-with sorghum or maize) and different irrigation frequencies (Continuous up to maturity, from planting up to vegetative stage, and rainfall dependent-as control). Each treatment constituted 10 lines or rows (i.e., eight plus two border rows) each row planted with 6 individual plants at a spacing of

90 cm by 65 cm, thus totaling to 6 plants per line/row. The research design to be used with this research were Completely Randomized Block Design (CRBD), whereas the data analysis involved eight treatments as factors, the variety effect having two (2) factors for the improved or resistant varieties and the susceptible varieties and the four (4) research site factors, that is Nyegina, Busungu-Majita, Nyasilori, in Mara region and Msoga–Chalinze in Coast Region. The plant spacing was 65 cm by 90 cm, giving 17,094 plants ha–1. The Cassava experiment field gap filling was performed at 2 to 3 weeks after planting depending on the soil water availability and schedule rotation for all location research sites. Weeding was undertaken 4-6 times using a hand hoe and more frequently during the early younger stage before the canopy covers the soil and in the rainy season. However, prior to the research execution starts in each research site there was soil analysis sampling to determine and assess the fertility and nutrients status and its availability status. Therefore, before the incorporation of organic fertilizers into the respective treatment plots, the soil field samples were collected from each village locations research sites namely; - Nyegina, Busungu-Majita, Nyasilori, in Mara region and Msoga – Chalinze in Coast Region and sent to the Soil Science Laboratory at SUA for nutrient or chemical analysis (C, N, P, K, Ca and Mg) as described by Tel and Hagarty (1984), prior to research execution for agronomic treatment application under field condition. The soil samples were collected from the topsoil at 20 cm depth by the use of an auger before the establishment of the study for laboratory analysis. Soil pH, OC, soil texture and available P, N, and K are among the key soil quality attributes influenced by applications of soil organic amendments. Before application of compost FYM + fertilizer as soil amendments, soil samples from each experimental plot were analyzed for pH, organic carbon and available phosphorus, nitrogen, and potassium. Soil pH was determined in a 1:2.5 (w/v) soil: water suspension using a pH meter Mclean EO (1982) and the Walkley and Black-wet oxidation method as outlined by Nelson and Sommers (1986) was used for determination of soil organic carbon using the dichromate wet oxidation method. Whereas, the total N was determined by the Kjeldahl digestion method Bremner JM and Mulvaney CS (1982). And the Bray-1 method, Bremner JM, Mulvaney CS. (1982) was used to extract available P from acidic soils samples with pHwater less or equal to seven and Olsen method Nelson, Olsen and Sommers (1986) and Banerjee, P. and Prasad, B (2020) was used to extract P from alkaline soil samples with pHwater above seven. Irrespective of the extraction method used, extractable P in soil extracts was quantified following the phosphomolybdic-ascorbic acid colorimetric method using a UV-VS spectrophotometer FAO. (2010). However, alternatively, the grounded samples were digested with nitric-perchloric-sulphuric acid mixture for determination of P, K, Ca and Mg. Phosphorus was determined by colorimetry using the vanadomolybdate method, K was determined by a flame photometer and Ca and Mg were determined by using the EDTA titration method. However, the soil Bulk density (BD), particle size distribution and water holding capacity (WHC) were not analyzed from these soil samples. Due to the fact that this analysis was out of scope and budget constrain or limitation. Similarly, to the soil particle size analysis which was to be determined by pipette method (Gee and Bauders, 1986).

Furthermore, after the experimental set up and treatment application in each field of location sites, two months later after planting and sprouting we started collecting our data. Which were categorized into four major broad categories the growth, yield and productivity data which included parameter such as; - germination percentage (GP), plant sprouting (PS), plant stem height (PH), number of branches (NBR), leaf area size and shape (LASS), crop performance (CP) and plant canopy width or diameter (PC) were measured as growth parameters; and the aboveground biomass or vegetative yield (VEGYID) and fresh tuber root yield (RYID) measured as yield parameters. The disease categories parameter such as; - disease incidence status (presence or absence) (DSTT), disease type (DTY), root necrotic status (RNSS) and root necrotic score (SRNS) other diseases (ODIES) and disease severity (DSS) and pest's categories parameter such as; - Cassava green mites (MT), Whiteflies (BM) and other pests (PEO) these were mainly for quantitative data collection through Morphological detection means. Finally, the fourth category were for qualitative methods of disease detection through molecular analysis of cassava leaf samples which were both (together with the quantitative data) collected and obtained from systematically selected two plants per row out of eight (8) rows per plot (24). Cassava storage roots and the shoot stem (vegetative yield) were harvested at 9-10 months after planting in Chalinze-Msoga site and at

11-12 months in Mara region sites at Nyasirori, Busungu-Majita and Nyegina. All storage roots were rubbed free of soil and weighed immediately for fresh weight determination.

2.2.2.2 Experimental Design and Layout Fig.2

Mon	Crop rotation	Cover crop	Planting date	Irrigation	FYM	Mono x FYM x Irr	Irri+FYM +CR
Cassava	Bambara-nut	Cassava + Cowpea	October	Incessant	100 Kg	Cassava+100+ Incessant	Cassava+100+ Incessant
Cassava	Maize	Cowpea	February	Vege stage	60 Kg	Cassava+60+ Vegetative	Cassava+60+ Vegetative
Cassava	Cowpea	Cassava	April	Rainfed	20 Kg	Cassava+20+ Rainfed	Cassava+20+ Rainfed

Fig. 3 P=Ar x Sp

2.2.3 Data Collection

2.2.3.1 Weather data

The weather data particularly temperature and rainfall were collected on monthly basis in ℃ and (mm) temperature and rainfall respectively, as an average through satellite data source from TMA weather data which was collected at each village location site in both 2021/2022 and 2022/2023 cropping seasons.

2.2.3.2 Cassava growth, productivity and yield data

To assess cassava growth, productivity and yield in response to agronomic treatment application of compost FYM + fertilizer as soil fertility amendments, and irrigation supplementation. The growth, productivity and yield parameters were used, plant height (PH), plant canopy (PC) centimeters (cm) were measured from the soil level to the top of the highest shoot tip or leaves at regular sampling interval of 3 to 4 weeks starting from the 2nd month after transplanting (MATP) using a tape measure for all plants assessed i.e., 2 plants per row for all 20-24 plots. However, other parameters like number of branches (NBR) were measured by counting, whereas, the leaf area, size, shape, and abnormality (LSSA) and crop performance were assessed and scored using a scale (1-5) through visual observation.

2.2.3.3 Cassava yield data

To determine cassava yields roots (RYID) and vegetative (VEGYID) in response to agronomic treatments, application of compost FYM + fertilizer as soil fertility amendment, and irrigation supplementation. All cassava plants intended to harvest were uprooted i.e., 2 plants per row in each plot were harvested 9-10 months after transplanting planting (MATP) by uprooting. Following uprooting, the plant parts were separated into root tubers, leaf and stems, for root (RYID) and vegetative yield (VEGYID) respectively. The fresh weight biomass of each fraction was measured and recorded right in the field using a Portable Spring weighing balance Scale.

2.2.4 Preparation of Compost from FYM, crop residues, dry grasses and forest soils or Anthills.

Uncured Farm yard manure (FYM) was collected from animal shed (cattle) at each village location research site and heaped, piled or layered with dry grasses, crop residues (maize straw and leguminous cowpeas, and layers of forest (anthill soils) and left to decompose to form a compost for three (3) months to give ample time for the manure, dry grasses and crop residues to be cured, decompose and mixed up thoroughly with the soil and be converted to a more stable form for

use as a compost fertilizer or biofertilizer used to be used as soil amendment. The tendency of materials to be put in the pile speeds the action that allows the organic matter to break down into the compost, which is a dark, fine humus-like material. The compost heaps were layered at wider or higher spacing than 2.5-3.5 m, and 1.5-2.5 m height depend on the availability of materials and the amount of compost needed or required However, during FYM manure decomposition, heat is generated that kill weed seeds, parasites and bacteria which cause plant diseases. Standard procedures FAO (2010) for pit or heap method of compost preparation (CP) were employed in all village location research sites at Nyasirori-Butiama, Nyegina and Busungu-Majita sites with some modification. In the procedure and modification adopted with this finding, the materials used for compost fertilizer (CP) making were crop residues maize straw, legumes cowpeas straw, dry grasses, sawdust or wood shavings, cattle farm yard manure (FYM), forest old anthill soil and ash. Then the materials were heaped, piled or layered starting with maize straws and dry grasses followed by a layer of farm yard manure (FYM), then anthill forest soil and some amount of ash, thereafter followed by a layer of leguminous cowpeas and sawdust or wood shavings, followed by farm yard manure (FYM) and ash, then covered with anthill forest soil. The layers were then repeated successively until the heap was up. Moreover, both crop residues and dry grasses were piled at 15-20 cm layer thickness, followed by thin layers of cattle farm yard manure (10 cm thick), ash (0.5 kg) and lastly the anthill forest soil (5-10 cm thick). The heap was forked into the middle to make a center hole to lower layers, and thus allow water to be poured and sprinkled to maintain moisture content of the materials at 60% FAO. (2010); Shitindi et al. (2019). A built-up compost heap will heat up, reaching temperatures as high as 60°C to 80°C. Therefore, after pulling the heap up to the top maximum height, a stick was inserted at the center of the heap for temperature checking. After about 15-21 days, the temperature of the compost will drop and the heap should be turned over, which means that the bottom layers should be brought to the top. The heap mixture was turned twice (2) regularly at an interval of three weeks (21days) for three months. Compost heaps were kept moist (at about 45% to 65% r.h). Thus, water was regularly sprinkled after every 4-6 days and turns to maintain the moisture content at 55% and 60% and temperature regulation. Finally, by the end of three (3) months, the compost fertilizer (CP) was cured and mature ready for use under field conditions.

2.2.2.3 FIELD STATION BLOCK SIZE 1,980.0 M^2 (0.5 Acres) Experimental Design and Layout.

8 Treatments - Varieties - V1-V9																
		Cropping System							**Agronomic Practice**				**Interaction Effect**			
Blocks	**Mono-cropping A**		**C. Rotation B**		**Cover Crop C**		**Planting dates D**		**Irrigation-F**		**FYM-Compost-E**		**Mono X FYM X Irr**		**Irr X FYM X CR**	
	V1.1	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**
	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2
	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2
	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2
	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2
	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2
Main Plot -	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2
A	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2
	V1.1	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**
	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2
	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2
	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2
	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2
	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2
Main Plot-	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2
B	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2
	V1.1	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**	**V1.1**	**V1.2**
	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2	V2.1	V2.2
	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2	V3.1	V3.2
11 m	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2	V4.1	V4.2
	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2	V5.1	V5.2
	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2	V6.1	V6.2
Main Plot-	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2	V7.1	V7.2
C	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2	V8.1	V8.2
	5.5 m															

3. Data Analysis

Under field conditions the cassava crop response of the growth-productivity and parameters, yield and genotypes data obtained following the treatment application of agronomic practices, from each village location site for this study. And the ability of the genotype influence of cassava varieties, agronomic practices treatment factor, village location sites and the growth stages all were used to predict the response of the growth-productivity and yield parameters such as plant height (PH), plant canopy (PC), number of branches (NBR), leaf area size shape and abnormality (LSSA), crop performance (CP), root yield (RYID), and vegetative yield (VEGYID) which were subjected to the Generalized Model Analysis of variance (ANOVA), Covariance analysis and linear regression analysis model of GENSTAT software 18th Edition and the JMP PRO means statistical package procedure of SAS Institute 1995, 1997, or 2000 software. Thus, the ANOVA, Linear regression analysis and Covariance analysis were used to measure the effects of agronomic practice, location sites, cassava varieties (cultivars), and the growth stages as affected by the growth, productivity and yield parameters relationship. And in addition, MST and MSE and correlation analysis were employed to performed pairwise comparison to determine the association and correlation of the growth stages, agronomic treatments and varietal influence with the growth and productivity parameters. Where the treatment means were separated using the Turkey's, Fisher's Unprotected least significant test and Student-Newman-Keuls Test at $P < 0.01$, $P < 0.01$ and $P < 0.05$ level of significance embedded in the General Linear Model Procedure of GENSTANT and JMP PRO means statistical procedure of SAS Institute 1995, 1997, or 2000 software.

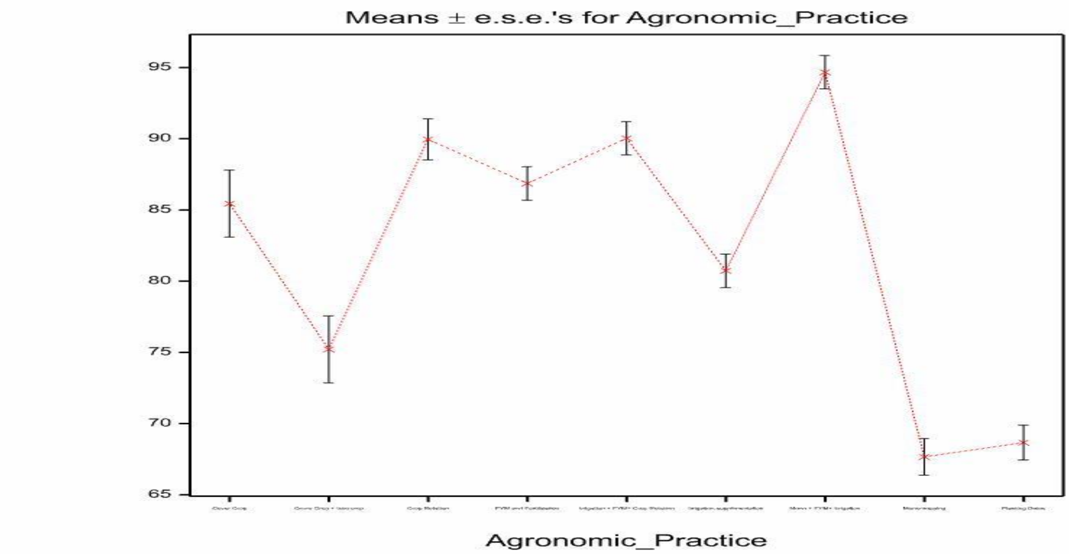
4. Results

4.1 Growth and Productivity Parameters

4.1.1 Growth Stage Influence

The growth and productivity parameters result in data in cassava including all other field crops, they provide the most important and useful information in various fields of agriculture, biology and diseases and pests incidence and infestation respectively. Thus, the growth and productivity data remain to be one of the main constraints limiting cassava production and productivity in several producer zones, particularly in the intervention location sites in Tanzania for this research and Sub-Saharan Africa in general. As the information for growth stages and productivity are particularly important as it tells when (what growth stage) is important to attend the crop for a particular management aspect, such as wedding, fertilizer application, pests and diseases control option or strategy. Similarly for the crop yields and maturity are also growth stage dependent, moreover, it thus, through the growth stage and cropping season of the year, the farmers can or a crop manager can predict the occurrence, incidence and time of infestation the diseases and pests respectively. However, copying from the growth stage advantage, the result of analysis of variance (ANOVA), JMP PRO SAS software and similarly GENSTAT regression analysis both showed and confirmed the observation that the agronomic practice treatment particularly the application of Compost FYM+ (Unique NPK 17:17:17 and Nitrabor CAN 26:15.4:0.3 B), Bio-fertilizer as crop biomass, solely or in combination with Irrigation supplementation interaction positively and significantly at $P < 0.001$ level of significance. They showed significance difference or varied effects on the influence of increasing growth and productivity parameters plant height (PH), plant canopy (PC), root yield (RYID) and vegetative yield (VEGY) in the two successive cropping seasons of 2021/2022 and 2022/2023 and single cropping season at Msoga Coastal and (Nyasirori, Majita and Nyegina villages of Mara location sites) respectively. While the growth stage and variety effects on growth and productivity parameters (PH, PC, NBR, LSSA, CP, RTY, and VEGY) assessed in all four (4) location sites in the Lake zone (Mara region) and Coast or Eastern zone (Pwani region) during the 2021/2022 and 2022/2023 of cassava growing season, similarly also showing significant difference at < 0.001 level of significance (Table 1a, 1b, 5a, 6a and 6b) and (Fig 1a, 2, 3, 7 and 8). However, in terms of regional growth and productivity performance generally Coast region had the highest growth for PH and PC than the Mara region with Msoga village location having the highest means followed by Nyasirori while Nyegina and Busungu-Majita showing the smallest means performance among the 4 village location sites.

Fig.1a Plant height (PH) variation effect with agronomic treatments.



Furthermore, the results suggested that there was significant influence of agronomic practices, cassava varieties and growth stages as treatment factors for all the growth productivity parameters starting with the plant height (PH) tested except the plant canopy (PC). However, the results also showed and confirmed that all of the growth and productivity parameters were increasing at an increasing rate with growth stages before crop plant maturity. Generally, significant and higher mean for plant height were recorded with Irrigation + FYM + Crop rotation, followed by Mono + FYM + Irrigation and Crop Rotation treatments with similar growth height effect (P< 0.001) (Table 6a, and 6b). And the higher plant height (PH) means were observed to be significantly higher with growth stages V, VI and peaked at growth stage VIII. Although there was a steady significant difference or variation between growth stage I and III, and also between stage V, IV and III and II with plant height (PH) at < 0.001 level of significance (Table 1a,1b, Fig7, and 8). However, some growth stages particularly, the growth stage I and II, III and IV, and V and VI showed no significance. And this is due to the fact that the cassava crop was at a very young stage to vegetative stage from 1 month to 4 months growth, where the cassava crop was characterized with slow growth rate and thus, therefore the crop was assumed to have a uniform growth rate. Whereas for the plant canopy (PC) showed no significance for both two factors under consideration the agronomic practices, and growth stages. And for the Number of branches the results findings showed that there were a significant different effect or variation for the number of branches with the agronomic practice's treatment and the growth stages at < 0.001 level of significance, except for the growth stage I and III and IV there after no significant variation as it maintained a uniform number of branching throughout the growing period (Table 5a, 6a, 6b, and 7). Where the highest means were shown by cover crop, planting dates and FYM fertilization treatments. And therefore, this refers to the botany and physiology of the crop that branching is primarily during the second and third growth stage only whereas the later branching on the upper part of the plant is regarded as secondary branching which are sympodial branching on which other successive branching are born, which latter after induction they form reproductive branching (Alves. 2002), and therefore are not considered as primary branching for that matter. Again, also the findings showed that there were a significance difference effect at < 0.001 level of significance, with the treatment of agronomic practices and the growth stage for both the Leaf area size shape and abnormality (LSSA) and the crop performance (CP), with growth stage at < 0.001 level of significance, however, more significant variation for both were shown only with growth stage I, II and III from the rest of the growth stages (Table 7, Fig 3, 34, 35, and 36). And this phenomenon in crop physiology and anatomical point of view justifies and signifies that normally at younger stages the leaf area, size shape and abnormality tend to be more uniform with no abnormality and were also the crop performance tends to be better at these younger stages compared to older growth stages as influenced by the prevailing weather condition for nutrients, moisture supply and drought conditions proximal to maturity respectively.

Fig.2 Number of branches (NBR) variation effect with agronomic treatments.

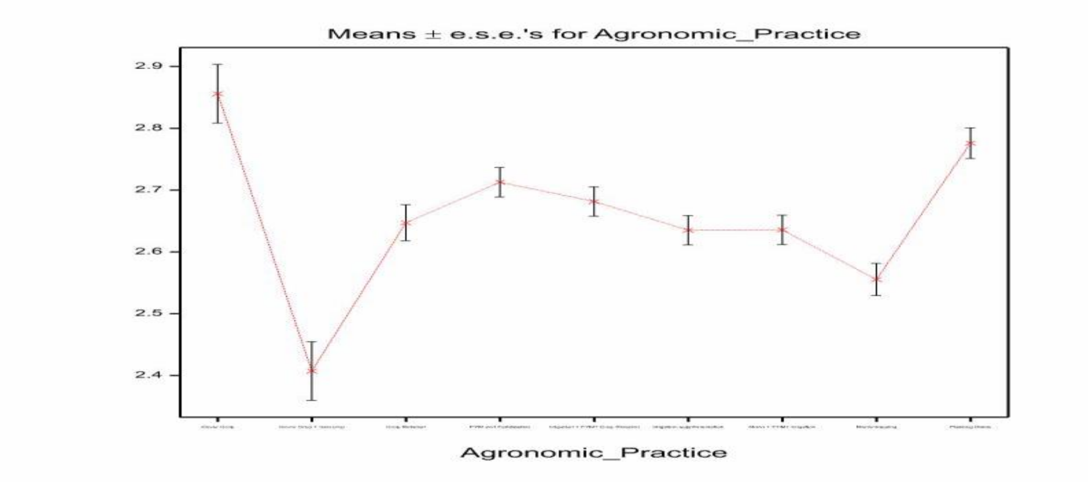
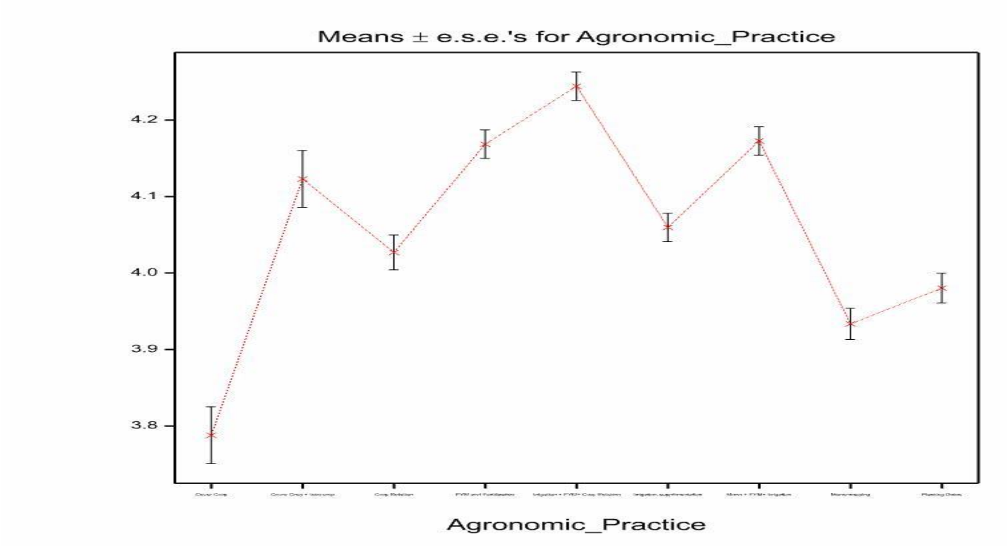


Fig.3. Leaf area, size shape and abnormality and Crop performance (LSSA &CP) variation effect with agronomic treatments.



4.1.2 Agronomic Practice Treatments Influence

Based from the information and data results from this research findings it was observed that, both manure FYM, Bio-Fertlizers, and Mineral fertilizers (Unique NPK 17:17:17 and Nitrabor CAN 26:15.4:0.3 B) materials either in combination or solely significantly increased the cassava crop performance and yield productivity of the growth and productivity variables or parameters at Msoga, Bagamoyo-Coast region and Nyasirori, Majita and Nyegina Butiama and Musoma rural, Mara region respectively in 2021/2022 and 2022/2023 cropping season. Therefore, the treatments effects results from this research findings further showed that there was a significant variation effect in terms of Plant height (PH) and Plant canopy (PC) at < 0.001 level of significance, with higher mean effects being shown by Mono + FYM + Irrigation, and Crop rotation and Irrigation +FYM + Crop rotation having the same effect followed by FYM and Fertilization treatment (Table 6a, 6b and Fig 1a, 7, and 8). However, Monocropping, Cover Crop, planting dates and irrigation supplementation treatments recorded the least plant height (PH) for the growing period or season 2022/2023 (Table 6a, 6b, and Fig 1a, 7 and 8). Thus, the results findings confirm and justify the significance and relevance of the research objectives, that the application of FYM and fertilization solely or in combination with Irrigation supplementation either in monocropping system or crop rotation have a significant effect on growth and productivity of cassava, and therefore can increase the crop yield and productivity significantly if applied in cassava production systems or farming systems. The number of branches also showed significant effects with agronomic practices treatments, although there was no significant variation to most treatment applications for the agronomic practices and therefore the results confirm that application of FYM and fertilization and Irrigation supplementation does not increase the number of branches in general. However, there was a significant effect on the number of branches at < 0.001 level of significance with some of the treatment particularly for the Cover crop, Planting dates, Monocropping and Cover crop + Intercropping treatments (Table 6a, 6b, 7 and Fig 2). And this agronomic importance can be interpreted and recommended that for the cassava crop production the planting dates varies the number of branching and therefore more branching are formed for the first and main planting dates of October December as compared to the late planting dates of February April and this might be affected by the influence of season, temperature and rainfall prevailing during the growing period after planting. And these results are as well confirmed and justified by the plant sprouting (PS) and the growth stages of cassava crop. Likewise, there were fewer branches for the Cover crop, Monocropping and Cover crop + Intercropping treatments. And this is agronomically obvious as the field with continuous monocropping the crop performance and fertility are significantly reduced which in turn affects the plant growth performance including the number of branches. Similarly, to the Cover crop + Intercropping as this tends to create crop plant competition for light, nutrients and moisture and therefore as all being a function of crop density the cassava crop plant thus tends to physiologically reduce its number of branches accordingly. Furthermore the results findings showed that the agronomic practices treatment have significant different effect at P < 0.001 level of significance, on the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) similarly, with the Irrigation + FYM + Crop rotation, Monocrop + FYM + Irrigation and FYM and Fertilization having higher significance level (means) and with the lowest (least) means being for the Monocropping and Cover cropping treatments (Table 6a, 6b, 7, Fig 3, 34, 35, 36, 37 and 38). Therefore, the treatment application of Compost FYM+ Fertilization solely or in combination increased both cassava fresh root yield (RYID) and the vegetative yield (VEGYID) compared to an unamended control and the other agronomic treatment tested. And thus, showed a significant difference or variation effects at < 0.001 level of significance for both the Root yield (RYID) and the Vegetative yield (VEGYID) (Fig 4, 5, 6a and 6b).

4.1.3 Cassava Varieties Influence

The result showed that the cassava varieties effect these research findings in the Lake zone (Mara region) and Coastal zone (Coast or Pwani region) during the 2021/2022 and 2022/2023 cassava growing season. Again, the findings also showed that with exception to Plant canopy (PC), all other growth and productivity parameters which were assessed starting with plant height (PH), showed there were a significant difference or variation effects at < 0.001 level of significance (Table 6a, 6b, and 7). However, generally for both parameters Kipusa and Mkuranga 1 varieties showed the highest mean height among the 8 varieties assessed in this experimental field research, while Chereko and Rwabhakanga showed the lowest means. However, a significantly different effect was shown only with Kipusa, Mkuranga 1 and the Rwabhakanga varieties at < 0.001 level of significance (Table 6a, 6b, and 7). And therefore, this effect can be associated with the disease resistance or tolerance and intolerance effects on growth, productivity, yield and crop field performance which have been shown by the three varieties Kipusa, Mkuranga 1 and Kiroba. And therefore, similarly

Kigori, Kirati and Rwabhakanga had shown a significantly higher rate of disease incidence and severity which in turn have caused stunted growth, which affected its growth rate in terms of height, canopy and crop performance in general. Furthermore, for the number of branches the findings showed that there was a significant variation with varieties where the Rwabhakanga and Mkuranga 1 varieties showed higher rates of branching and number of branching.

This effect might be influenced by their genetic Vigor as supported by their environmental interaction effects. Moreover, the variety effects for this finding again confirmed and showed that there were a significant variation effects at < 0.001 level of significance, in terms of both Leaf area size shape and abnormality (LSSA) and Crop performance (CP), whereas Mkuranga 1 and Kipusa varieties had the highest LSSA and CP mean, while Kigori, Kirati and Rwabhakanga had the least or lowest means respectively (Fig.3, 34, 35, 36, 37 and 38). Moreover, in all four (4) research location sites, Msoga of Coastal or Pwani region, Majita, Nyasirori and Nyegina of Mara region, treatment application of Compost FYM+ Fertilization solely or in combination increased both cassava fresh root yield (RYID) and the vegetative yield (VEGYID) compared to an unamended control and the other agronomic treatment tested (Fig 4, 5, 6a, and 6b). The influence of agronomic practices, therefore as it was found to improve the soil total porosity and water or moisture holding capacity, decreases the soil bulk density. Soil water holding capacity and total porosity increased as organic manure rates increased, while soil bulk density decreased with increased organic manure (FYM) rates. Thus, growth stages, location sites and cassava varieties as the treatment factors also considered here for the growth productivity parameters again, they all showed a significant difference or variation effects at < 0.001 level of significance for both the Root yield (RYID) and the Vegetative yield (VEGYID) (Fig 4, 5, 6a, and 6b).

Fig.4 Root Yield (RYID) variation effect with agronomic treatments.

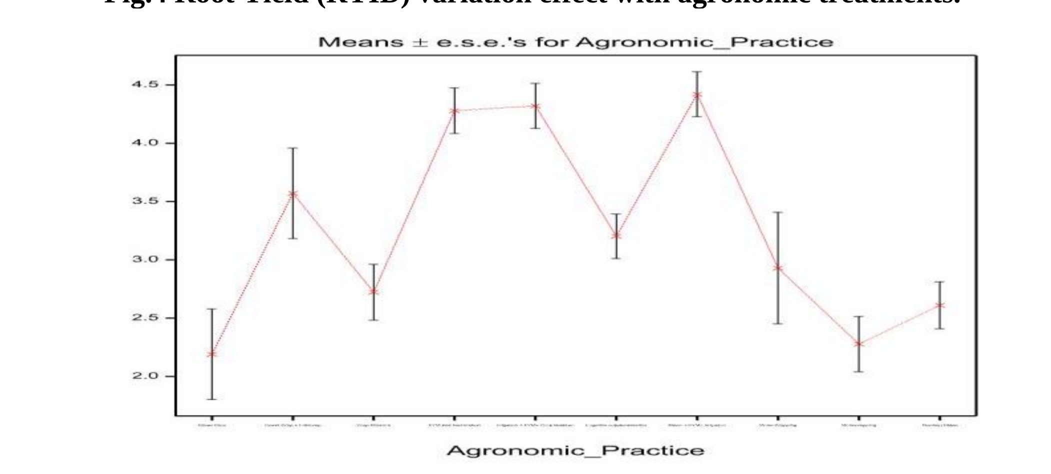


Fig.5 Vegetative Yield (VEGYID) variation effect with agronomic treatments.

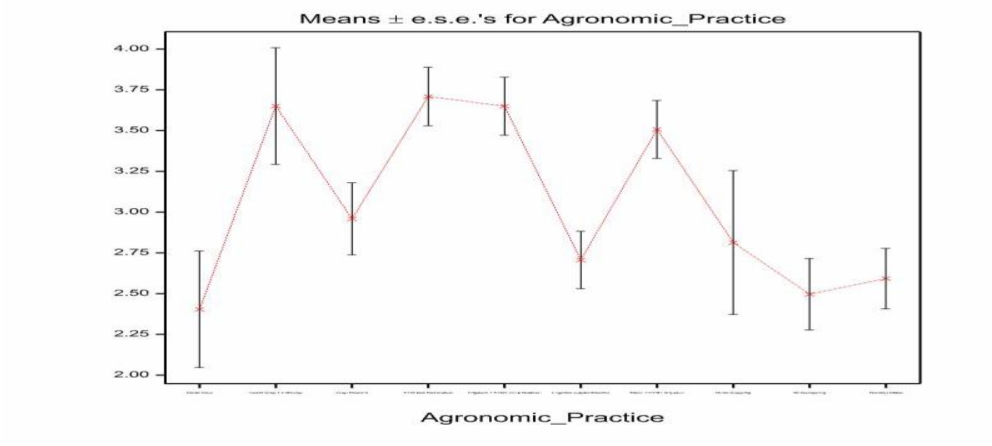


Fig.6a. Root yield (RYID) variation effect with agronomic treatments.

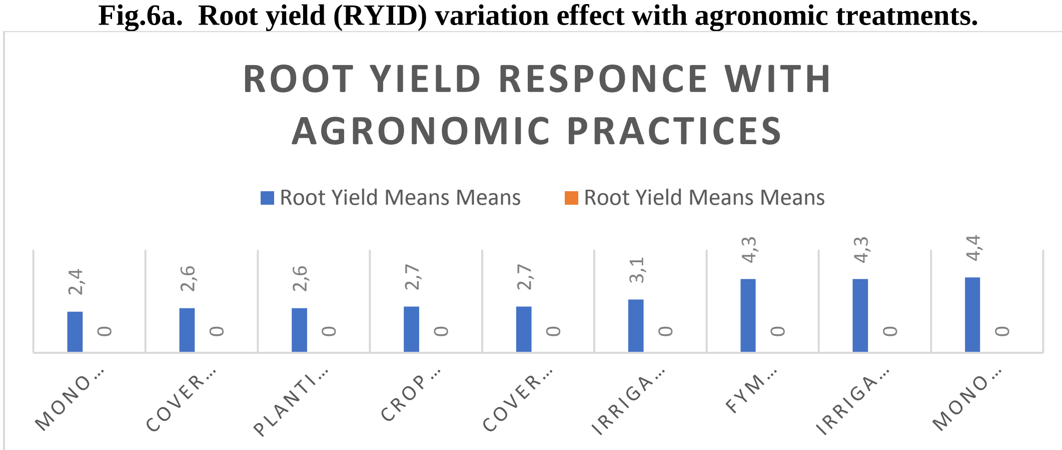


Fig.6b. Vegetative yield (VEGYID) variation effect with agronomic treatments.

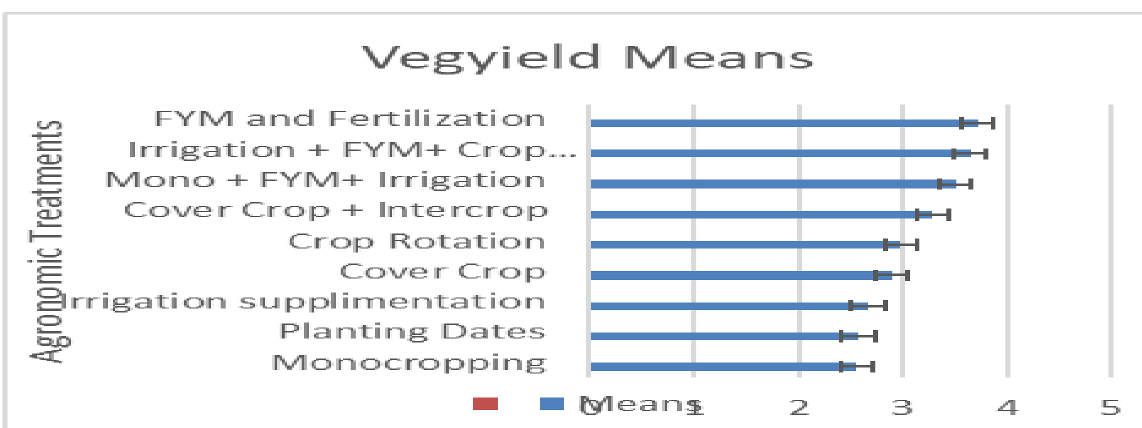


Fig. 7. Variation of Plant height (PH) with Growth stages

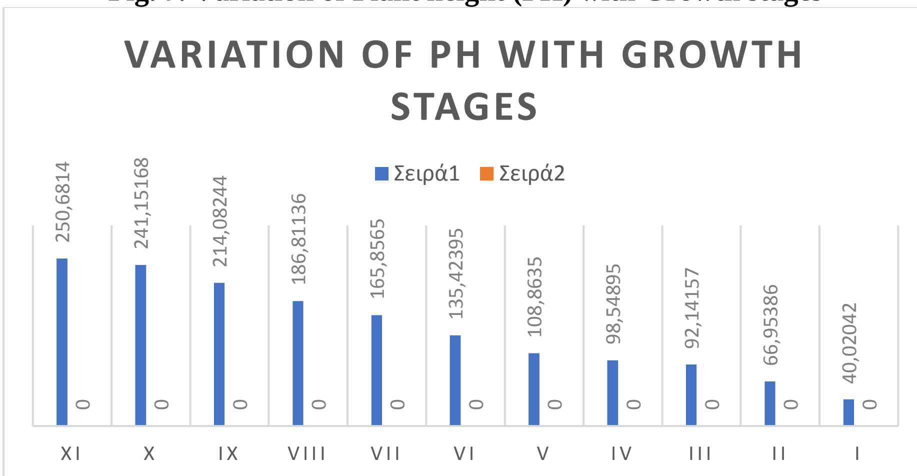
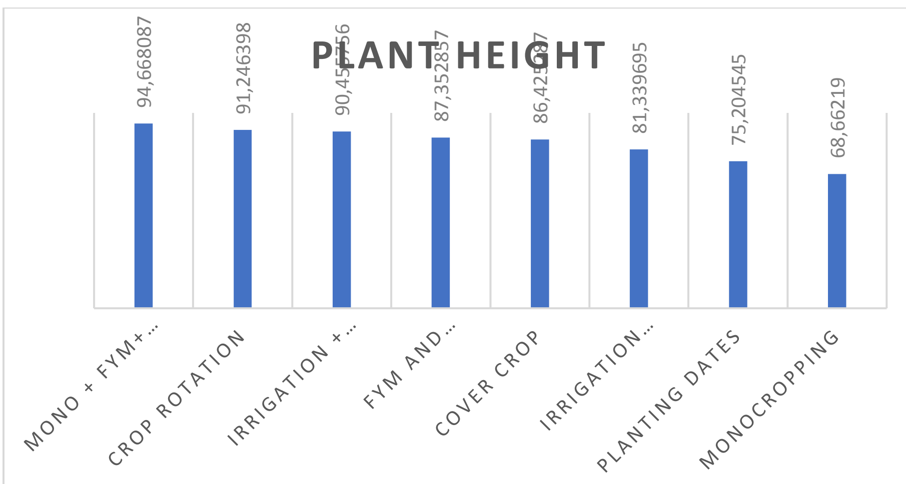


Fig. 8. Variation of Plant height (PH) with agronomic treatment application



But overall yields were not affected by higher rates of Compost+Fertilizer application and least Root and Vegetative yields were realized with treatments Monocropping, Planting dates, Cover crops, and Irrigation supplementation solely. And similarly, as for the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) again Mkuranga 1, Kiroba and Kipusa varieties had the highest meanwhile Kigori, Kirati and Rwabhakanga had the lowest mean respectively (Table 6a, 6b, Fig 34, 35, 36, 37 and 38). And therefore, the three (3) varieties performed poorly in terms of growth and productivity and yield parameters. Therefore, both growth and yield parameters were significantly affected by the amendments (agronomic practices) applied (Table 6a, and 6b). And again, the correlation analysis in (Fig 10), thus this important observation on variety effect for the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) have revealed a positive and strong correlation and association between or with the diseases CMD and CBSD incidence, status, type and severity. And similarly for the Root yield (RYID) and Vegetative yield (VEGYID) also showed strong positive and significance correlation at < 0.001 level of significance (Fig 9).

Fig. 9. Correlation analysis

Correlations

RNSS1A	1	-			
RYID1	2	-0.3082	-		
SRNS1A	3	0.7652	-0.293	-	
VEGYID1	4	-0.1721	0.6329	-0.122	-
		1	2	3	4

Number of observations: 664

Two-sided test of correlations different from zero

RNSS1A	1	-			
RYID1	2	<0.001	-		
SRNS1A	3	<0.001	<0.001	-	
VEGYID1	4	<0.001	<0.001	0.002	-
		1	2	3	4

This correlation and association which have been shown by this relationship. In terms of both agronomically, anatomical and physiological points of view can be interpreted and justified by the fact that the appearance of a normal leaf for leaf area, size, shape and abnormality (LSSA). Therefore, this correlation refers to and influences the good or better cassava crop performance agronomically under field condition in terms of better crop performance (CP), Root yield (RYID) and Vegetative yield (VEGYID). And therefore, the better and normal the leaf the better the crop performance (CP), Root yield (RYID) and the Vegetative yield and vice versa is true. And thus, it means that the growth and productivity and yield performance of the crop are much more dependent and influenced by the soil physical properties and their embedded nutrients availability status.

Fig 34. A, B, C Mkuranga 1 Var, Cassava crop showing varietal variation response of growth, crop productivity and performance in different growth stages at Nyasirori location sites.

Fig 35. D, E, F Kipusa and Rwabhakanga vars respectively, Cassava crop showing varietal variation response of growth, crop productivity and performance in different growth stages at Nyasirori location.

Fig 36. A, B, Cassava crop stand under experimental field showing varietal variation response of growth, crop productivity and performance in different growth stages at Msoga location sites.

Fig 37. C, D, E Chereko, Rasta, Mkuranga 1 vars respectively, Cassava crop showing varietal variation response of growth, crop productivity and performance in different growth stages at Msoga location.

Fig 38. F, G, H Kiroba, Mkuranga 1 and Kipusa vars respectively, Cassava crop showing varietal variation response of growth, crop productivity and performance in different growth stages at Msoga location sites.

Table 1a. Regression or (REML), Analysis of Variance (ANOVA)

Variate: PH1						Variate: PC1				
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Regression	28	25150092	898218	616.7	<.001	28	1.28E+08	4563395	0.96	0.528
Agronomic_Practice	8	673973	84247	57.82	<.001	8	3.04E+07	3.79E+06	0.8	0.606
Growth_Stage	10	15267218	1526722	1048	<.001	10	5.36E+07	5.36E+06	1.12	0.339
Regions	1	2369338	2369338	1626	<.001	1	1.97E+05	1.97E+05	0.04	0.839
Village_site	3	6751537	2250512	1545	<.001	3	1.12E+07	3.75E+06	0.79	0.501
Varieties	7	159483	22783	15.64	<.001	7	3.25E+07	4.64E+06	0.97	0.449
Residual	7274	10597770	1457			7274	3.47E+10	4.77E+06		
Total	7303	35746852				7303	3.48E+10			

Variate: LSSA1 & CP1						Variate: NBR1				
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Regression	28	1808	64.5879	177.2	<.001	28	1582	56.5065	94.67	<.001
Agronomic_Practice	8	99.7848	12.4731	34.22	<.001	8	54.4423	6.8053	11.4	<.001
Growth_Stage	10	101.137	10.1137	27.74	<.001	10	50.8155	5.0816	8.51	<.001
Regions	1	0.1178	0.1178	0.32	0.57	1	43.5037	43.5037	72.88	<.001
Village_site	3	243.6286	81.2095	222.8	<.001	3	3.8521	1.284	2.15	0.092
Varieties	7	1366.3195	195.1885	535.5	<.001	7	1447.586	206.798	346.42	<.001
Residual	7274	2651.6177	0.3645			7186	4289.772	0.597		
Total	7303	4460.0441				7215	5871.953			

Table 1b. Regression or (REML), Analysis of Variance (ANOVA)

Change of Variation	variate: RYID1 d.f.	s.s.	m.s.	v.r.	F pr.	variate: VEGYID1 d.f.	s.s.	m.s.	v.r.	F pr.
Regression	18	2320	128.863	36.15	<.001	18	1798	99.908	33.06	<.001
+ Agronomic_Practice	8	441.323	55.165	15.47	<.001	8	220.103	27.513	9.11	<.001
+ Location	3	1561.067	520.356	146	<.001	3	1483.984	494.661	163.7	<.001
+ Varieties	7	317.15	45.307	12.71	<.001	7	94.265	13.466	4.46	<.001
Residual	645	2299.366	3.565			645	1949	3.022		
Total	663	4618.906	6.967			663	3747.351	5.652		

Table. 5a. Environmental and agroecological influence on cassava growth, productivity and disease incidence and severity

Source of variation		Growth and Productivity					Disease parameters			
		PH	PC	NBR	LSSA	CP	DSTT	DTY	DSS	PBM
Region	Coast	117.8a	114.8a	2.5b	4.1a	4.1a	1.3b	0.5b	1.8b	0.3a
	Mara	70.7b	63.8b	2.7a	4.1a	4.1a	1.4a	0.7a	1.9a	0.3b
Villages	Nyasirori	122.2a	103.5b	2.8b	4.4a	4.4a	1.3b	0.6b	1.6c	0.3ab
	Nyegina	49.8b	49.2c	2.7b	4.0c	4.0c	1.4a	0.8a	2.0a	0.3b
	Busungu-Majita	45.3b	42.6d	2.7ab	3.9c	3.9c	1.4a	0.7b	2.0a	0.3b
	Msoga	117.8a	114.9a	2.6c	4.1b	4.1b	1.3b	0.5c	1.9b	0.3a

***Means with different letters along the column differ significantly at P < 0.001 level of significance.

Table. 6a. Effects of Agricultural practices on cassava growth, productivity, yield and diseases incidence and severity

Source of variation	Growth and Productivity					Disease parameters			
	PH	PC	NBR	LSSA	CP	DSTT	DTY	DSS	PBM
Mono + FYM+ Irrigation	94.7a	85.9a	2.6cd	4.2a	4.2a	1.3cde	0.5c	1.8cd	0.3a
Crop Rotation	91.2ab	85.7ab	2.6bcd	4.1b	4.1b	1.4ab	0.7ab	2.0a	0.3a
Irrigation + FYM+ Crop Rotation	90.5ab	84.4ab	2.7abc	4.2a	4.2a	1.3de	0.6bc	1.8d	0.3a
FYM and Fertilization	87.4abc	81.6ab	2.7abc	4.2a	4.2a	1.4bcd	0.5c	1.8bcd	0.3a
Cover Crop	86.4abc	78.7ab	2.9a	4.0cd	4.0cd	1.3de	0.7ab	2.0abc	0.3a
Irrigation	81.3bc	75.7abc	2.7cd	4.1ab	4.1ab	1.4ab	0.7b	2.0ab	0.3a
Planting Dates	75.2cd	73.1abcd	2.8ab	4.1ab	4.1ab	1.4abc	0.7b	2.0a	0.3a
Monocropping	68.7d	65.5abcd	2.6de	4.0bc	4.0bc	1.5a	0.9a	2.0ab	0.3a

***Means with different letters along the column differ significantly at P < 0.001 level of significance.

Table. 6b. Environmental and agroecological response of Cassava varieties on growth, productivity and disease incidence and severity

Source of variation	Growth and Productivity					Disease parameters			
	PH	PC	NBR	LSSA	CP	DSTT	DTY	DSS	PBM
Kipusa	89.7a	85.7a	2.7c	4.5b	4.5b	1.1f	0.1e	1.5e	0.3a
Mkuranga 1	88.5a	83.2ab	2.9b	4.6a	4.6a	1.0g	0.0f	1.3f	0.3a
Kirati	85.4ab	78.3abc	2.7c	3.8e	3.8e	1.6c	1.0b	2.1b	0.3a
Kigori	83.4ab	73.1c	2.2f	3.8e	3.8e	1.6b	1.1b	2.2b	0.3a
Rasta	83.0ab	77.4abc	2.2f	4.3c	4.3c	1.2e	0.4d	1.9c	0.3a
Kiroba	81.6ab	74.c	2.4e	4.2d	4.2d	1.4d	0.8c	1.8c	0.3a
Chereko	77.5b	74.bc	2.6d	4.2d	4.2d	1.2e	0.4d	1.7d	0.3a
Rwabhakanga	75.5b	70.7c	3.7a	3.2f	3.2f	1.9a	1.2a	2.7a	0.3a

***Means with different letters along the column differ significantly at P < 0.001 level of significance.

Table. 7. Environmental effects of growth stages on cassava growth, productivity and disease incidence and severity parameters

Source of variation	Growth and Productivity					Disease parameters			
	PH	PC	NBR	LSSA	CP	DSTT	DTY	DSS	PBM
I	40.0e	20.0h	2.5b	4.3a	4.3a	1.2e	0.3d	1.7e	0e
II	67.0e	27.0h	2.6ab	4.3a	4.3a	1.3d	0.5c	1.69e	0e
III	92.1d	42.1g	2.6a	4.2a	4.2a	1.3cd	0.6bc	1.8de	0e
IV	98.5d	48.5g	2.7a	4.0b	4.0b	1.4abc	0.67ab	1.87cd	0.02e
V	108.9cd	58.9f	2.6a	4.0b	4.0b	1.4a	0.7a	2.1ab	0.28cd
VI	135.4c	65.4f	2.7a	3.9b	3.9b	1.4abc	0.6abc	2.1a	0.29c
VII	165.9ab	85.9e	2.7a	3.9b	3.9b	1.4bcd	0.57bc	2.1ab	0.75b
VIII	186.8a	96.8d	2.7a	4.0b	4.0b	1.4abc	0.66ab	1.9abc	0.96a
IX	214.1ab	114.1c	2.7a	4.0b	4.0b	1.4ab	0.7a	1.88cd	0.7b
X	241.2b	141.2b	2.7a	4.0b	4.0b	1.4abc	0.7a	1.9cd	0.23d
XI	250.7a	150.7a	2.7a	4.03b	4.03b	1.4abc	0.7a	1.9bc	0e

***Means with different letters along the column differ significantly at $P < 0.001$ level of significance.

5. Discussion

5.1 Growth, productivity and yield Parameters

5.1.1 The Influence of agronomic treatment on Growth Stage

The growth, productivity and yield parameters result from this finding in cassava crops including all other field crops, as influenced by the growth stages. They provide the most important and useful information not only in the field of agriculture, but also in the applied botany, biology and diseases and pests incidence and infestation respectively. Thus, the growth and productivity data remain to be one of the main constraints limiting cassava production and productivity in several producer zones, particularly in the intervention location sites in Tanzania, and Sub-Saharan Africa in general. As the information for growth stages and productivity are particularly important as it tells when (what growth stage) is important to attend the crop for a particular management aspect, such as wedding, fertilizer application, pests and diseases control option or strategy. Similarly for the crop yields and maturity are also growth stage dependent, moreover, it thus, through the growth stage and cropping season of the year, the farmers can or a crop manager can predict the occurrence, incidence and time of infestation the diseases and pests respectively.

Cassava growth performance and productivity is largely dependent on weather and prevailing environmental conditions. Therefore, being as an important environmental limitation, drought has become a rising concern due to its harm to development and productivity of crop plants Putpeerawit, P., Sojikul, P., Thitamade, S and Narangajavana, J (2017); Sedaghat, M., Tahmasebi-Sarvestani, Z., Emam, Y. and Mokhtassi-Bidgoli, A. (2017). Being one of the most important crops in tropical areas (Scott et al., 2000), Cassava (*Manihot esculenta* Crantz) is a major staple food crop in most parts of Africa; thus, playing an important role in terms of food security, employment and source of income for many families (Spencer and Ezedinma, 2017). Cassava is a major staple food to resource-limited people in marginal areas because of its ability to survive and produce in such poor land with infrequent rainfall and low fertility Turyagyenda, L. F. et al. (2013); Zhao, P. J. et al., (2015); Putpeerawit, P., Sojikul, P., Thitamade, S and Narangajavana, J (2017). Senkoro et al., (2018) reported that, Pests and diseases, the use of poor cultural practices, and low soil fertility status are among causal factors for low cassava yields, similar result findings were also reported by (Harvest Choice, 2011; Ezui et al., 2016) growth and productivity. Therefore, the plant development or growth stages of the compost FYM + Fertilizer treated treatment plots with Irrigation supplementation or without was growing vigorously and at a faster growth rate particularly during the heavy rain season of around March-April up to late May. Whereas, the growth rates and development from the other non-treatment of Compost FYM+ Fertilizer plots and control treatment were very slow and poor. Thus, all growth, productivity and yield parameters particularly plant height (PH), plant canopy (PC), plant girth (PG), they showed and confirmed by the earlier observation that the agronomic practice treatment particularly the application of Compost FYM+ (Unique NPK 17:17:17 and Nitrabor CAN 26:15.4:0.3 B), Bio-fertilizer as crop biomass, solely or in combination with Irrigation supplementation interaction they showed positively and significance variation or difference or growth, productivity, and yield at $P < 0.001$ level of significance. However, similar results were reported by Munyahali et al. (2024), that application of NPK + FYM resulted in significant increase in plant height (PH), plant girth or stem diameter (SD) over time, independent of the variety and total biomass, storage root yield and stem yield by 38% (11.5 t per ha), 25% (5.1 t per ha), and 65% (6.5 t per ha), respectively relative to the unfertilized and control treatments. Similarly, crop performance (CP), root yield (RYID) and vegetative yield (VEGYID) were significantly lower at $P < 0.001$ level of significance with the none Compost FYM + Fertilizer + Irrigation supplementation (with or without) and the control treatment as compared to the Compost FYM + Fertilizer applied plots. They all showed significant differences in the two successive cropping seasons of 2021/2022 and 2022/2023 and single cropping season at Msoga Coastal and (Nyasirori, Majita and Nyegina villages of Mara location sites) respectively. However, for Msoga village location site in Coastal region which had two cropping seasons, the 2021/2022 and 2022/2023 cropping season the growth, productivity and yield for the season 2021/2022 were significantly lower compared to season 2022/2023 from the Compost FYM + Fertilizer + Irrigation application plots and the none treatment plots and control treatment plot. Similarly, with their growth stage and variety effects on growth and productivity parameters (PH, PC, NBR, LSSA, CP, RTY, and VEGY) assessed in all four (4) location sites in the Lake zone (Mara region) and Coast or Eastern zone (Pwani region) during the 2021/2022 and 2022/2023 of cassava growing season, similarly also showing significant difference at < 0.001 level of significance. And this was assumed to be influenced much with variation in weather conditions particularly, rainfall and temperature in each respective cropping season or production year. Similar results were reported by John Constantine and Angellka Hillbeck (2023), that although total rainfall recorded in 2020/21 season was lower than that of 2019/20 season in both sites, cassava yields recorded in 2020/21 season surpassed that of 2019/20. Again, in the same study John Constantine and Angellka Hillbeck (2023), further they reported that Compost application significantly increased cassava plant height (P = 0.05) at both Masasi and Mvomero sites. In both 2019/20 and 20220/21 cropping seasons there was an increase in cassava plant height with increase in CP application rates at Mvomero site, however the increase was not significantly different (P > 0 .05). In both seasons, the lowest cassava plant heights were recorded in untreated plots. This was attributed to improved ability of soil to retain moisture following application of either CP or FYM. However, in terms of regional growth and productivity performance generally Coast region for the two cropping seasons had the highest growth for PH and PC than the Mara region with Msoga village location having the highest means followed by Nyasirori while Nyegina and Busungu-Majita showing the smallest means performance among the 4 village location sites. Generally, significant and higher mean for plant height were recorded with Irrigation+FYM+Crop rotation, followed by Mono+FYM+ Irrigation and Crop Rotation treatments with similar growth height effect (P< 0.001) (Table 6a and 6b). And the higher growth rates of plant height (PH), higher mean differences were observed to be significantly higher with growth stages IV, V, VI and peaked at growth stage VIII. The study by Munyahali et al. (2024), also confirmed and found that without the application of NPK + FYM fertilizer the average storage root yields of the local variety were higher in the first growing year than in the second year, but comparable for the improved variety during the two experimental years in Congo DRC. Similarly, the same study also found that, when applying NPK + FYM Fertilizer storage, root yields obtained with both local and improved varieties were higher in 2014 than 2015 Munyahali et al. (2024). Similarly, the findings showed that there were a significance difference effect at < 0.001 level of significance, with the treatment of agronomic practices and the growth stage for both the Leaf area size shape and abnormality (LSSA) and the crop performance (CP), with growth stage at < 0.001 level of significance, however, more significant variation for both were shown only with growth stage I, II and III from the rest of the growth stages. And this phenomenon in crop physiology and anatomical point of view justifies and signifies that normally at younger stages the leaf area, size shape and abnormality tend to be more uniform with no abnormality and were also the crop performance tends to be better at these younger stages compared to older growth stages as influenced by the prevailing weather condition for nutrients, moisture supply and drought conditions proximal to maturity respectively.

However, some growth stages particularly, the growth stage I and II, III and IV, and V and VI showed no significance. And this is due to the fact that the cassava crop was at a very young stage to vegetative stage from 1 month to 4 months growth, where the cassava crop was characterized with slow growth rate and thus, therefore the crop was assumed to have a uniform growth rate. Whereas for the plant canopy (PC) showed no significance for both two factors under consideration the agronomic practices, and growth stages. And for the Number of branches the results findings showed that there were a significant different effect or variation for the number of branches with the agronomic practice's treatment and the growth stages at < 0.001 level of significance, except for the growth stage I and III and IV there after no significant variation which existed as it maintained a uniform number of branching throughout the growing period. Where the highest means were shown by cover crop, planting dates and FYM fertilization treatments. And therefore, this refers to the botany and physiology of the crop that branching is primarily during the second and third growth stage only whereas the later branching on the upper part of the plant is regarded as secondary branching which are sympodial branching on which other successive branching are born, which latter after induction they form reproductive branching (Alves. 2002), and therefore are not considered as primary branching for that matter.

5.1.2 The influence of Agronomic treatment

Based on the information and data results from this research findings it was observed and suggests that, both manure FYM, Bio-Fertlizers, and Mineral fertilizers (Unique NPK 17:17:17 and Nitrabor CAN 26:15.4:0.3 B) materials either in combination or solely significantly increased the cassava crop performance and yield productivity at Msoga, Bagamoyo-Coast region and Nyasirori, Majita and Nyegina Butiama and Musoma rural, Mara region respectively in 2021/2022 and 2022/2023 cropping season. Plant height (PH) and Plant canopy (PC) showed higher significant variation at < 0.001 level of significance, with higher mean effects being shown by Mono + FYM + Irrigation, and Crop rotation and Irrigation +FYM + Crop rotation having the same effect followed by FYM and Fertilization treatment. However, Monocropping, Cover Crop, planting dates and irrigation supplementation treatments recorded the least plant height (PH) for the growing period or season 2022/2023. And similarly, the same effect was shown for the 2021/2022 cropping season at Msoga village location site. Field data results for this study correlates highly, for the growth, productivity and yield of cassava in terms of plant height (PH), plant canopy (PC), plant stem diameter (girth) (SD), crop performance (CP) root yield (RYID) and vegetative yield (VEGYID) with the former results findings by Biratu et al. (2018a, b) and Kolawole et al. (2014); John Constantine and Angellka Hillbeck (2023); Munyahali et al., (2023) and recently, but to a lesser extent, with that of Mabrouk A. El-Sharkawy (2003). The study by Munyahali et al. (2024), also confirmed and found that without the application of NPK + FYM fertilizer the average storage root yields of the local variety were higher in the first growing year than in the second year, but comparable for the improved variety during the two experimental years in Congo DRC. Similarly, the same study also found that, when applying NPK + FYM Fertilizer storage, root yields obtained with both local and improved varieties were higher in 2014 than 2015 Munyahali et al. (2024). Likewise, Gervais Bilong et al. (2022), they noted similar findings that regardless of the cropping season, increasing the rate of organic fertilizers increased growth and yield of cassava with the best performance in cassava growth and yield parameters were recorded on plots treated with TB and PM in the second cropping season (2017/2018). This was probably due to the residual effects of accumulation effects of OM and available nutrients after repeated addition of organic fertilizers amendments. These findings were confirmed by those of Biratu et al. (2018a, b) and Kolawole et al. (2014) who noticed an increase on growth and yield parameters of cassava on further increase of different organic fertilizers. Thus, therefore the results findings confirm and justify the significance and relevance of the research objectives, that the application of FYM and fertilization solely or in combination with Irrigation supplementation either in monocropping system or crop rotation have a significant effect on growth and productivity of cassava, and therefore can increase the crop yield and productivity significantly if applied in cassava production systems or farming systems. Although the number of branches also showed significant effects with agronomic practices treatments, there was no significant variation to most treatment applications for the agronomic practices, as they were found largely to be variety and weather dependent. And therefore, the results suggest that application of FYM and fertilization and Irrigation supplementation does not increase the number of branches in general. Moreover, there was a significant effect on the number of branches at < 0.001 level of significance with some of the treatment particularly for the Cover crop, Planting dates, Monocropping and Cover crop +Intercropping treatments. And this in an agronomic importance and point of view can be interpreted and recommended that for the cassava crop production the planting dates varies the number of branching and therefore more branching are formed for the first and main planting dates of October December as compared to the late planting dates of February April and this might be affected by the influence of season, temperature and rainfall prevailing during the growing period after planting. Which similarly were supported by the plant sprouting (PS) and the growth stages of cassava crop. Likewise, there were fewer branches for the Cover crop, Monocropping and Cover crop + Intercropping treatments. And this is agronomically obvious as the field with continuous monocropping the crop performance and fertility are significantly reduced which in turn affects the plant growth performance including the number of branches. Similarly, to the Cover crop + Intercropping as this tends to create crop plant competition for light, nutrients and moisture and therefore as all being a function of crop density the cassava crop plant thus tends to physiologically reduce its number of branches accordingly.

Furthermore, the agronomic practices treatment was significantly varied at < 0.001 level of significance, on the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) similarly, particularly with the Irrigation + FYM + Crop rotation, Monocrop +FYM + Irrigation and FYM and Fertilization having higher significance level (means) and with the lowest (least) means being for the Monocropping and Cover cropping treatments. And similarly, Root yield (RYID) and the Vegetative yield (VEGYID) both showed significant higher variation effects at < 0.001 level of significance with the agronomic treatment application treatments of Mono or crop rotation + FYM + Irrigation and FYM + Fertilizer relative to the other treatments tested and the control treatment. Therefore, conclusively it can be hypothesized that the treatment application of Compost FYM+ Fertilization solely or in combination increased both cassava fresh root yield (RYID) and the vegetative yield (VEGYID) compared to an unamended control and the other agronomic treatment tested. The results thus, corresponds with the findings obtained by John Constantine and Angellka Hillbeck (2023), FYM significantly (P=.05) increased the number of cassava tubers per plant as well as cassava tuber fresh weight Significant difference (P =.05) were observed between treatment means with regards to numbers of tubers per plant at both Masasi and Mvomero sites. The highest number of tubers were recorded from the highest CP application rate, which were 10.5 and 13.4 for Mvomero and Masasi respectively. At both Mvomero and Masasi sites, there was a significant (p =.05) difference between the different levels of FYM on cassava shoot and root weight and similarly, the regression correlation analysis results by John Constantine and Angellka Hillbeck (2023), also reported that there was a strong positive relationship between cassava fresh yield and leaves, stems and total above ground biomass following application of FYM. Cassava plant height (PH), plant canopy (PC) and plant stem diameter (girth) (SD) are among the good indicators of cassava growth, productivity, development and yield determinants. Generally, in all of the agronomic treatments application of Compost + FYM + Fertilizers and Irrigation supplementation with monocrop or crop rotation cropping system treated plots, the greatest improvement of these variables as growth, productivity and yield determinant were recorded in the application rates of 100 kg and 60 kg per row at all village location sites. However, Nyegina and Busungu-Majita village location sites require higher rates of 100 kg. And with a shorter application frequency of once per season or twice per year in two (2) or three (3) successive cropping years. Compared to other two village location sites of Msoga Bagamoyo district Coastal region and Nyasirori Butiama district Mara region. Due to their inherent poor soil characteristics of being sandy-sandy loam and sandy loam soil with more coarse texture.

Conversely, several research works and literature which were supporting this observation of the impacts suggesting that increased growth, productivity and yield, were due to soil improvement and amendments. Through addition of organic matter by composting and FYM with this finding were also reported by Gervais Bilong et al. (2022), who showed that soil water holding capacity and total porosity increased as organic manure rates increased, while soil bulk density decreased with increased manure rates. Furthermore, the applications of TB and PM, solely or mixed at different rates, reduced soil bulk density by 14–26%, increased total porosity by 10–16% and water holding capacity by 13–30%, compared to the control. Application of mineral fertilizer (MF) had no significant effect on soil physical parameters Gervais Bilong et al. (2022). Significant changes were noticed on soil physical properties for both cropping seasons (2016/2017 and 2017/2018) but were better improved in the second cropping season (2017/2018) compared to the first (2016/2017). The improvement of the growth and yield of cassava with Tithonia diversifolia fresh biomass (TB) and poultry manure (PM) applied solely or combined was a result of improved soil physical parameters. The poor performance of cassava recorded from the unamended plots (control) was probably due to their soil physical conditions and their low content of soil organic matter (Hafifah et al., 2016; Agbede et al., 2017; Agbede, 2021). Supporting observations with these findings were also observed and reported by Kolawole et al. (2014) and Pravin et al. (2013).

5.1.3 Cassava Varieties Influence

This study findings has demonstrated that, varietal differences existed for the growth, productivity and yield of cassava in terms of plant height (PH), plant canopy (PC), plant stem diameter (girth) (SD), crop performance (CP), diseases incidence and severity CMD and CBSD, root yield (RYID) and vegetative yield (VEGYID parameters assessed with the most of the local, inferior and susceptible genotype, having an overall lower growth, productivity and yield population than improved varieties and moderately resistant genotype regardless the cropping season, growth stages and agronomic treatments applied. Therefore, the cassava varieties affect these research findings in the Lake zone (Mara region) and Coastal zone (Coast or Pwani region) during the 2021/2022 and 2022/2023 cassava growing season. Also showed that with exception to Plant canopy (PC), all other growth and productivity parameters which were assessed starting with plant height (PH), showed there were a significant difference or variation effects at < 0.001 level of significance. However, generally for both parameters Kipusa and Mkuranga 1 varieties showed the highest mean height among the 8 varieties assessed in this experimental field research, while Chereko and Rwabhakanga showed the lowest means. Similar results were reported by Munyahali et al. (2024), that application of NPK + FYM resulted in significant increase in plant height (PH), plant girth or stem diameter (SD) over time, independent of the variety and total biomass, storage root yield and stem yield by 38% (11.5 t per ha), 25% (5.1 t per ha), and 65% (6.5 t per ha), respectively relative to the unfertilized and control treatments. However, a significantly different effect was shown only with Kipusa, Mkuranga 1 and the Rwabhakanga varieties at < 0.001 level of significance. And therefore, this effect can be associated with the disease resistance or tolerance and intolerance effects respectively on growth, productivity, yield and crop field performance which have been shown by the three varieties Kipusa, Mkuranga 1 and Kiroba. And therefore, similarly Kigori, Kirati and Rwabhakanga had shown a significantly higher rate of disease incidence and severity which in turn have caused stunted growth, which affected its growth rate in terms of height, canopy and crop performance in general.

Furthermore, for the number of branches the findings showed that there was a significant variation with varieties at < 0.001 level of significance where the Rwabhakanga and Mkuranga 1 varieties showed higher rates of branching and number of branching. Conversely, the study by Mabrouk A. El-Sharkawy (2003), also reported and supporting this results that the branching or forking behavior of stems (after the top buds turn into reproductive ones) varies widely among cultivars, ranging from zero to about four branches per branching point (initiated from the axillary buds below the point of branching) (Tan and Cock, 1979). Timing and height of the first branching point also varies among cultivars, with some branching earlier than others Mabrouk A. El-Sharkawy (2003). This effect might be influenced by their genetic Vigor as supported by their environmental interaction effects. Moreover, the variety effects for this finding similarly, confirmed and showed that there were a significant variation effects at < 0.001 level of significance, in terms of both Leaf area size shape and abnormality (LSSA) and Crop performance (CP), whereas Mkuranga 1 and Kipusa varieties had the highest LSSA and CP meanwhile Kigori, Kirati and Rwabhakanga had the least or lowest means respectively. Moreover, in all four (4) research location sites, Msoga of Coastal or Pwani region, Majita, Nyasirori and Nyegina of Mara region, treatment application of Compost FYM+ Fertilization solely or in combination increased both cassava fresh root yield (RYID) and the vegetative yield (VEGYID) compared to an unamended control and the other agronomic treatment tested. Similarly, Munyahali et al. (2024), also found that, when applying NPK + FYM Fertilizer storage, root yields obtained with both local and improved varieties were higher in 2014 than 2015. The influence of agronomic practices, therefore as it was found to improve the soil total porosity and water or moisture holding capacity, decreases the soil bulk density. Soil water holding capacity and total porosity increased as organic manure rates increased, while soil bulk density decreased with increased organic manure (FYM) rates. Thus, growth stages, location sites and cassava varieties as the treatment factors also considered here for the growth productivity parameters again, they all showed a significant difference or variation effects at < 0.001 level of significance for both the Root yield (RYID) and the Vegetative yield (VEGYID).

But overall yields were not affected by higher rates of Compost + Fertilizer application and least Root and Vegetative yields were realized with treatments Monocropping, Planting dates, Cover crops, and Irrigation supplementation solely. Therefore, the best and suitable compost manure application rates could be an average between and within the range of 70 kg and 60 kg per row which is equivalent to 40 and 35 t Per ha. And similarly, as for the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) again Mkuranga 1, Kiroba and Kipusa varieties had the highest index value and therefore performed better compared to varieties like Kigori, Kirati and Rwabhakanga have the lowest mean respectively and thus indicating poor performance. And therefore, the three (3) varieties performed poorly in terms of growth and productivity and yield parameters. Therefore, both growth and yield parameters were significantly affected by the amendments (agronomic practices) applied. And again, the correlation analysis for the Leaf area size shape and abnormality (LSSA) and Crop performance (CP) in this study also confirm and provide important observation on variety effect which revealed a positive and strong correlation and association between or with the diseases CMD and CBSD incidence, status, type and severity. And similarly for the Root yield (RYID) and Vegetative yield (VEGYID) also showed strong positive and significance correlation at < 0.001 level of significance. Therefore, correlation and association suggest agronomically, anatomical and physiological points of view, that the appearance of a normal leaf for leaf area, size, shape and abnormality (LSSA) refers to and associated to influences the good or better cassava crop performance agronomically under field condition in terms of better crop performance (CP), Root yield (RYID) and vegetative yield (VEGYID). And therefore, the better and normal the leaf the better the crop performance (CP), Root yield (RYID) and the vegetative yield and vice versa is true. And thus, it means that the growth and productivity and yield performance of the crop are much more dependent and influenced by the soil physical properties and their embedded nutrients availability status.

6. Conclusion Remarks and Recommendation

Conclusively, since, the objective of this research study was to determine the influence of compost FYM + fertilization and irrigation supplementation on growth, productivity and yield response of cassava, following the estimates and analysis of the total contributing factors to the decline of crop productivity and yield performance, increased rate of diseases incidence, virulence, severity and persistence in Mara and Pwani Region-Tanzania. Thus, however, the contributing factors found were mainly cultural, agronomical, lack of proper phytosanitation measures, poor cropping systems, lack of disease resistant and disease-free varieties, loss of soil fertility, and poor rainfall availability. However, this research study managed to come out with tangible contributing factors to the decline and low vegetative growth, productivity and yield in the intervention villages, districts and regions. The findings confirmed that the problem was mainly associated to be due to lack (unavailability and inaccessibility) of improved varieties (disease resistant), continually planting and use of susceptible and dirty (infected) planting materials cuttings particularly in Mara region. Furthermore, the contributing factors were also associated or caused by inherent poor soil characteristics (for moisture holding capacity) and fertility prolonged drought and rainfall availability. Moreover, the control measures now advocated depend on the availability and accessibility of CBSD and CMD disease-free cuttings and of suitably resistant varieties, and also on the preference and willingness of farmers to adopt this material and to practice at least some degree of fertilization by applying FYM, practice irrigation supplementation where there is little or low rainfall amount and distribution, phytosanitation and crop deployment. While the improved cassava varieties evaluated such as Kipusa, Mkuranga, Kiroba and Chereko showed better performance in terms of growth, productivity and yield in the village location sites within the two regions and a significant level of disease resistance for both CBSD and CMD. Mkuranga, and Kipusa showed high levels and degree of field performance for growth, productivity and yield compared to Kiroba and Chereko, similarly for disease resistance or tolerance. Moreover, although these improved varieties showed resistance, they performed poorly under field conditions with poor soil fertility and little moisture supply or drought conditions particularly to none irrigation supplementation treatments. Thus, the findings conclusively advocate, recommend and promote the use of cultural methods/strategy particularly application of compost FYM + fertilization amendments with or without irrigation supplementation as a strategy for increased cassava growth, productivity and yield response in Mara and Coastal regions and at the same time for disease management, prevention and control.

Furthermore, the findings of this research study showed that regional, village location sites influence performance, although all showed significant differences in the two successive cropping seasons of 2021/2022 and 2022/2023 and single cropping season. However, Nyasirori and Msoga showed superior performance in all parameters assessed for growth, productivity and yield. although for Msoga village location site in Coastal region which had two cropping seasons, the 2021/2022 and 2022/2023 cropping season the growth, productivity and yield for the season 2021/2022 were significantly lower compared to season 2022/2023 from the Compost FYM + Fertilizer + Irrigation application plots and the none treatment plots and control treatment plot. Similarly, with their growth stage and variety effects on growth and productivity parameters (PH, PC, NBR, LSSA, CP, RTY, and VEGY) assessed in all four (4) location sites in the Lake zone (Mara region) and Coast or Eastern zone (Pwani region) during the 2021/2022 and 2022/2023 of cassava growing season, similarly Msoga and Nyasirori showing significance higher performance than the other two village location sites of Nyegina and Busungu-Majita. And this was assumed to be influenced much with variation in weather condition particularly, rainfall and temperature in each respective cropping season or production year. And therefore, this phenomenon justifies the research hypothesis on the influence of Agroecology, Environmental condition. As climate and weather prevailing in each respective region and also soil factors, importance on cassava growth, productivity and yield response in the study regions.

Therefore, agronomic treatment application of Compost FYM + Fertilizers with or without irrigation supplementation either in monocropping or crop rotation significantly at $P < 0.001$ level of significance not only improve cassava growth, productivity and yield response they have a spillover effect of improving soil texture and characteristics particularly to poor soils and sand one, with an added advantage of increasing water holding capacity (moisture) and regulating soil temperature for better crop growth and performance with longer shelf life thus resilient and sustainable. However, the best results and recommended application rates of compost FYM were found to be ranging between 40 and 60 kg per row equivalent to 20.0-32.0 t ha-1 application rates depending on soils type (i.e., too poor and too sandy or sandy-sandy loam) and fertility status of the soil.

CONFLICT OF INTERESTS

The authors have not declared any competing or conflict of interest (s) regarding this publication work.

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