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Effect of Cattle Manure and Calcium Ammonium Nitrogen on Growth and Leaf Yield of Local Cowpea Accessions in Coastal Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MJH, FKM, JA, AWM, FO and JJO designed the study. Authors FKM and MJH wrote the protocol and wrote the first draft of the manuscript while author MJH wrote all other drafts of the manuscript. Authors FKM and MJH managed the literature searches. Authors FKM and MM collected the accessions and managed the experimental process. Author FKM conducted the analyses of the study performed. All authors read and approved the final manuscript.

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ABSTRACT

Cowpea is one of the major food crops contributing to food security and poverty alleviation especially among women and resource-poor farmers in marginal areas in Kenya. The effect of different concentrations of cattle manure and inorganic nitrogen (Calcium ammonium nitrate, CAN) application on growth and fresh and dry leaf yields from single and multiple harvest of four local vegetable cowpea accessions, Mnyenze madamada, Sura mbaya, Katsetse and Usimpe mtu mdogo, was studied over two seasons at Mtwapa in coastal Kenya. The research was conducted in a randomized complete block design with three replications with treatments arranged in a factorial arrangement. Analysis of variance was carried out on the data using Genstat Statistical package

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and means were compared using LSD at 5% level of significance (P=.05). Application of cattle manure and inorganic nitrogen fertilizer CAN had no effect or slightly decreased root length and had no effect on the number of branches per plant irrespective of seasons. The application of organic and inorganic fertilizers increased plant height, canopy width and fresh and dry weights depending on the season. The plants planted during the second and drier second season had lower growth and yield attributes compared to those planted during the first season. Of significance was the significant yield increase from multiple harvests with indications of yield improvements from as low as 1.5-4.0 tons/ha to between 15-20 tons/ha. Calcium ammonium nitrate was more effective compared to cattle manure during the dry season compared to the wet season, when cattle manure significantly increased yields (P>.05). The four select local cowpea accessions responded positively to the organic and inorganic fertilizers over seasons and therefore have the capacity to address food security and income generation in marginal parts of Kenya.

Keywords: Cowpeas; fertilizer application; local accessions; Vigna unguiculata.

1. INTRODUCTION

Though neglected in the past, there is renewed interest and support for African leafy vegetables (ALV) research as an income generation alternative and a key pillar for food and nutrition security strategy among smallholder farmers in Kenya. Cowpea (*Vigna unguiculata* L. Walp.) is among the most popular indigenous ALVs consumed in Eastern and Southern Africa both as grain and leaf. In many areas, cowpea has been produced by smallholder women farmers in small home gardens mainly for its protein-rich grains, usually under intercropping production system. Its ability to withstand drought, short growing period and multi-purpose use make it a very attractive alternative crop for farmers in marginal, drought-prone areas with low and erratic rainfall [1]. Despite the dramatic increase in cowpea production in Sub-Saharan Africa, cowpea yields remain one of the lowest among all food legume crops averaging 450 kg/ha [2]. Its yields are low due to several constraints including poor soil and use of low yield variety of seeds as planting material. In addition to its importance in human food, cowpea is also useful for soil fertilization through symbiotic nitrogen fixation and can be a major animal feed due to the quality of its leaves [3]. Kilifi in Coastal Kenya is one of the poorest counties in Kenya with average poverty and food insecurity figures ranging between 70 and 90% [4]. Cowpea is the most important ALV in Kilifi County and the whole coastal region of Kenya and is a major source of dietary protein, especially for the rural and urban poor [5]. The major constraints facing the production of cowpeas in the coastal Kenya include unavailability of quality seed, lack of technical packages along the entire value chain and general lack of awareness of the potential the crop holds in mitigating poverty and malnutrition challenges in the community [5]. The cowpea, just like other ALVs is still viewed as a 'woman's' crop among rural communities and has therefore not received sufficient attention in a strongly patriarchal system [6]. Variety development has mainly occurred for varieties with high yield of grain. Consequently there are few varieties recommended for use as vegetable cowpea. Even fewer studies have been conducted to develop appropriate agronomic/ production packages for improved yields and nutrition. In the recent past, KARI has released high yielding cowpea varieties such as KVU and K-80 [7]. The rate of uptake among farmers, however, has been low with farmers having a strong preference for local accessions that are said to be more palatable despite the low yields compared to the improved varieties [7]. Low soil productivity is a major constraint in small holder farms in coastal lowlands of Kenya [5,8]. To our knowledge, there has been no study focusing on local cowpea accessions that are more popular with the local community and are likely to be on their nutritional radar. Most of the research that has looked at the effect of organic and inorganic fertilizer has focused on elite and improved varieties [9,10]. Application of NPK fertilizer in small quantities to cowpea was reported to be beneficial and genotype dependent [11] although cowpea has been reported to grow well in poor soils that have more than 85% sand, less than 0.2% organic matter and low levels of phosphorous [12]. Cowpea requires more P than N fertilizer because it fixes its own N from the air using nodules in its roots [13]. However, in areas where soils are poor in N, there is need to apply a small quantity as a starter dose for a good crop. If too much N fertilizer is used, the plant will grow luxuriantly with poor grain yield [2] and would therefore be beneficial for leafy vegetable use. Phosphorus fertilizer significantly enhanced growth and yield characters of the cowpea varieties used; plant height, leaf area, number of leaves and number of branches in all the weeks of measurement were significantly improved [14]. Phosphorus also had a significant effect (P=.05) on seed yield per treatment, weight of 50 seeds, number of nodules, weight of nodules and total above-ground dry matter in all varieties used. However, variations were observed in the responses of the different cowpea varieties to phosphorus application.

The objective of this study, therefore, was to determine the response of four select local vegetable cowpea accessions to cattle manure and calcium ammonium nitrogen application in a sandy loam soil in coastal Kenya.

2. MATERIALS AND METHODS

2.1 Location of the Study

The research was conducted at Kenya Agricultural and Livestock Research Organization (KALRO) Mtwapa in Kilifi County in coastal lowland in Kenya. The area has an altitude of 30 m a.s.l., a longitude of 39° 45'East, a latitude of 4° South and a high relative humidity of more than 80%. Coastal lowland 3 is characterized by semi-humid conditions with an annual rainfall of 800-1400 mm and temperature range of 24-30℃. Lowland 4 is characterized by semi-humid to semi-arid conditions and a rainfall of 600-1100 mm/year and average temperatures of about 24-32℃. The rainfall in Mtwapa is bimodal with the long rains starting in April/May up to August. Short rains start in October and extend to December. The soils are sandy with pH in the range of 5.3 to 6.9.

2.2 Plant Material

Four high yielding and popular local cowpeas accessions, Mnyenze madamanda, Sura mbaya, Katsetse and Usimpe mtu mdogo, were collected from two agro-ecological zones (Coastal Lowland 3 and Coastal Lowland 4) in Kilifi and Mombasa counties in April 2012. The limited seed was bulked at the KALRO Mtwapa Research station, and the seed used to raise the crops used during the trials. Before planting was done, soil and nutrient analyses were carried out on the experimental field.

2.3 Experimental Design

The experiment was laid out as a randomized complete block design, and treatments arranged in a factorial manner with three replications.

2.4 Treatments

Four local cowpea accessions, Mnyenze madamanda, Sura mbaya, Katsetse and Usimpe mtu mdogo were planted on plots measuring 4m x 3 m with plant spacing of 60 cm x 30 cm. Three rates of cattle manure (7.8, 15.6, and 23.3 tons/ha) containing an average of 1.23% N, 0.48% P, 1.25% K, 1.16% Ca, 0.75% mg, 1116 mg/kg Fe, 14 mg/kg Cu, 404 mg/kg Mn, 99.2 mg/kg Zn was applied on the plots and thoroughly ploughed in two days before planting. Calcium ammonium nitrate (CAN) containing 26% N, was applied on plants three weeks after planting as a top dress at rates of 278, 416 and 555 kg/ha. Accessions grown on soil not supplemented with any form of fertilizer acted as controls. The cowpea accessions were planted in different plots during the different seasons to avoid residual nutrient effect. The crop was rain fed and the field kept weed-free manually.

2.5 Measurements Taken

The root length, plant height, canopy width, number of branches, fresh and dry weights of the leaves from single and multiple harvests and fresh and dry leaf yields were assessed. For single harvest yield assessment, harvesting was carried out one month after planting by uprooting six whole plants per plot. Multiple harvests started one month after planting and mature leaves from data plants were picked weekly and weighed. In season 1, nine harvests were done and harvesting period extended for one month. In the drier season 2, seven harvests were done over a period of 21 days.

The leaf dry weights was determined by drying them in an oven at 55℃ for 72 hours before weighing and dried in the oven for a further 72 hours for dry matter determination.

2.6 Data Analysis

Analysis of variance was carried out on data taken using Genstat Statistical Programme [15] and means separated using LSD at 5% level of significance (*P*=.05).

3. RESULTS AND DISCUSSION

The soils in the experimental site had low levels of nitrogen, carbon, phosphorous and potassium especially at the top soils (Data not shown). Other than zinc, the other micronutrients were adequate. The incorporation of various rates of cattle manure and calcium ammonium nitrate into the soils and the harvesting frequency influenced the growth and leaf yields of the four local cowpea accessions from Coastal part of Kenya.

Application of various rates of cattle manure and inorganic nitrogen (CAN) either had no effect or slightly decreased the root length of the 4 accessions (Figs. 1a and 1b), with higher concentrations of fertilizer suppressing root growth for Usimpe mtu mdogo and Sura mbaya local accessions (*P*=.05). Between seasons, Usimpe mtu mdogo grown on soils complemented with cattle manure produced the longest roots in season 1 compared to Katsetse in season 2. While there was no major difference between organic and inorganic fertilizer effects on root length, CAN promoted root elongation during the drier season 2 (Fig. 1b).

Nutrition of vegetables such as cowpeas is characterized by their shallow rooting habit and rapid growth rate. High growth rates necessitate adequate supply of nutrients throughout the vegetative period as observed in another ALV, *Cleome gynandra* grown in the Rift Valley of Kenya [16]. The beneficial effect of organic matter on crop productivity is a function of so many factors, which include greater vigor of plant, improvement of soil properties and greater uptake of nutrients [17].

Increasing the rate of cattle manure in the soils increased plant height of Usimpe mtu mdogo (over 55 cm in season 1) and Mnyenze madamada in season 1 (Fig. 2a) but had no effect in season 2 (Fig. 2b). Calcium ammonium nitrate on the other hand, had no effect on plant height in season 1 while promoting it during season 2 (Figs. 2a and 2b).

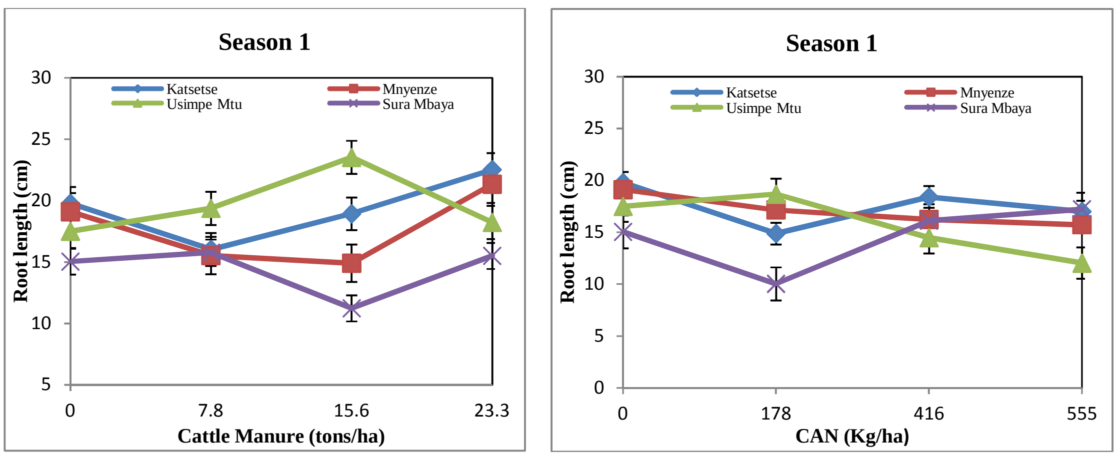

Fig. 1a. Effect of cattle manure and calcium ammonium nitrate (CAN) on root length (cm) of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

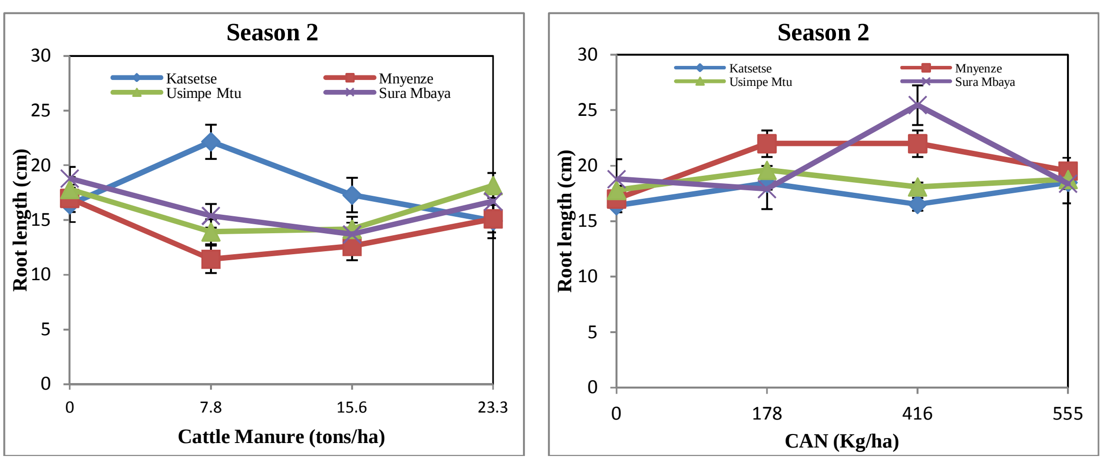

Fig. 1b. Effect of cattle manure and calcium ammonium nitrate (CAN) on root length (cm) of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

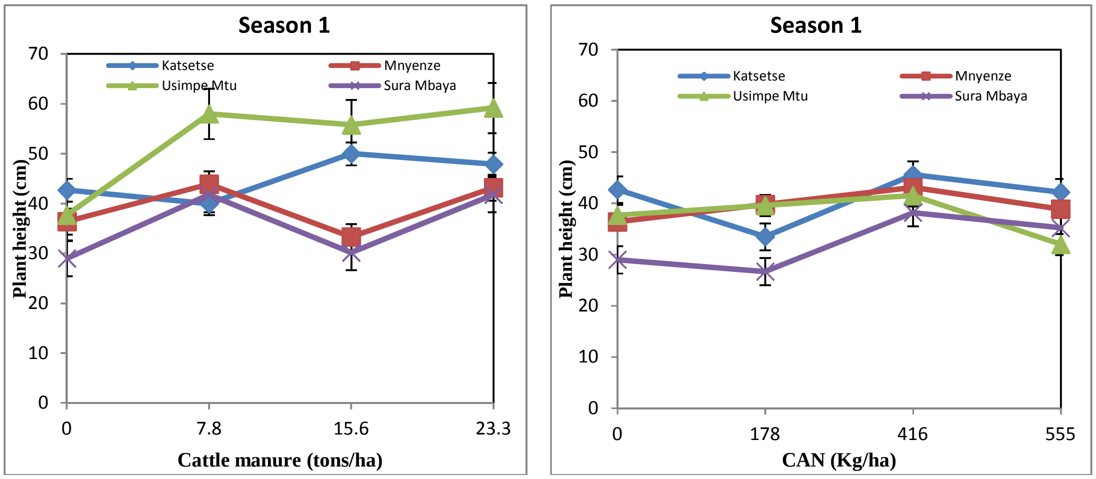

Fig. 2a. Effect of cattle manure and calcium ammonium nitrate (CAN) on plant height (cm) of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

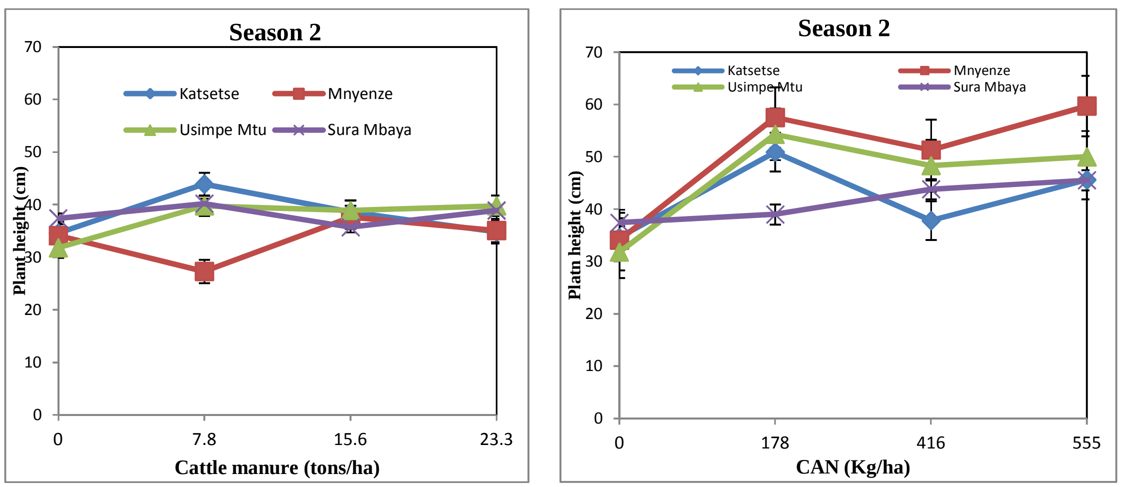

Fig. 2b. Effect of cattle manure and calcium ammonium nitrate (CAN) on plant height (cm) of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

Incorporation of cattle manure and CAN influenced canopy width of the 4 cowpeas accessions during both seasons of testing (Figs. 3a and 3b). Except for the plants grown on soils supplemented with cattle manure in season 2, Usimpe mtu mdogo, Katsetse and Mnyenze madamada had wider plant canopies of up to 120 cm compared to Sura mbaya that consistently had the smallest canopy. Treatment comparisons indicate that cattle manure was more effective in season 1 (Fig. 3a), while CAN increased the canopy width of the 4 local cowpeas accessions in season 2 (Fig. 3b).

Application of manure and inorganic nitrogen had no influence on the number of branches of the 4 cowpea accessions that all produced between 3 and 4 branches irrespective of season (Figs. 4a and 4b).

The fresh leaf yields harvested once were significantly affected by incorporation of cattle manure and CAN and frequency of harvesting (Figs. 5a and 5b). There were no differences in yield of plants planted in season 1 and season 2. In season 1, CAN had no effect while in season 2, its application doubled the fresh weight of Usimpe mtu mdogo and Mnyenze madamada at 178 kg/ha and 555 kg/ha, respectively. Increasing the rate of cattle manure, while having no effect in season 2, increased the fresh leaf yields of Usimpe mtu mdogo and Katsetse in season 1. Multiple harvesting had a tremendous increase in the fresh yields of cowpea leaves

(Figs. 5 and 6). In season 1, multiple harvesting of cowpea applied with cattle manure or CAN increased overall leaf yields from an average of about 1.5 tons/ha to 4 tons/ha increasing to between 15 and 20 tons/ha (Figs. 5 and 6).

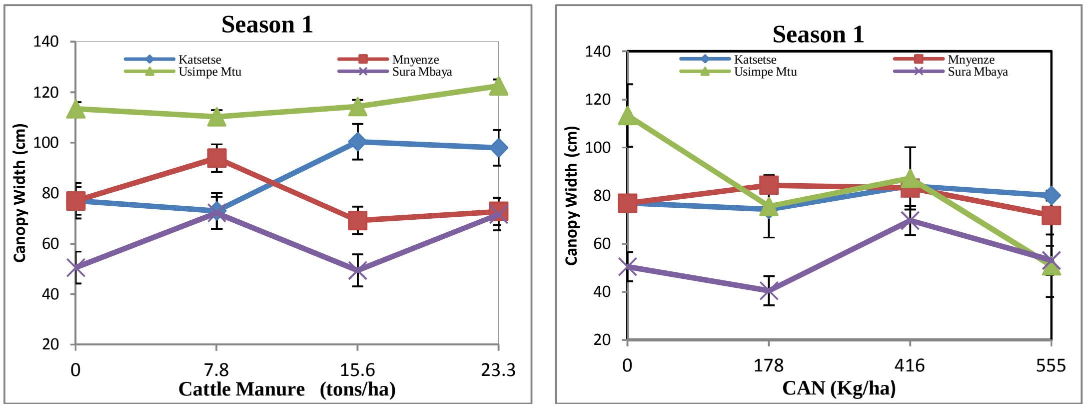

Fig. 3a. Effect of cattle manure and calcium ammonium nitrate (CAN) on canopy width (cm) of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

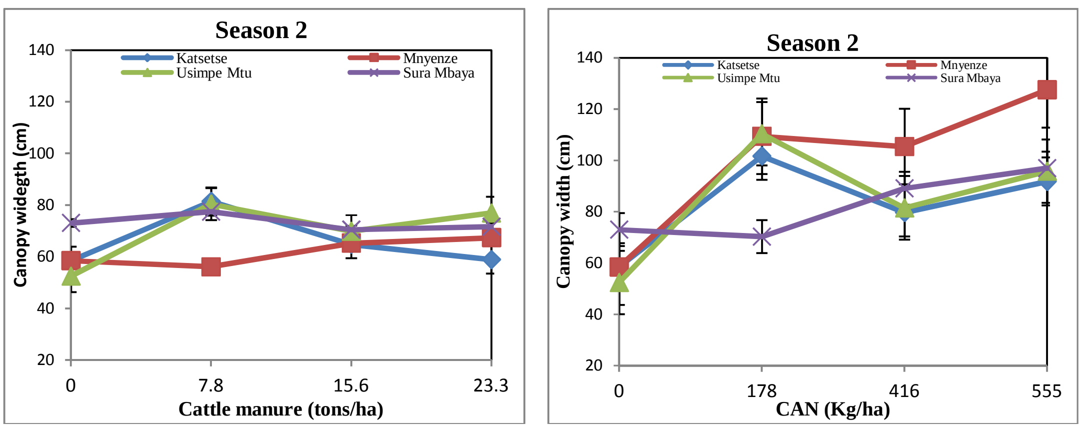

Fig. 3b. Effect of cattle manure and calcium ammonium nitrate (CAN) on canopy width (cm) of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

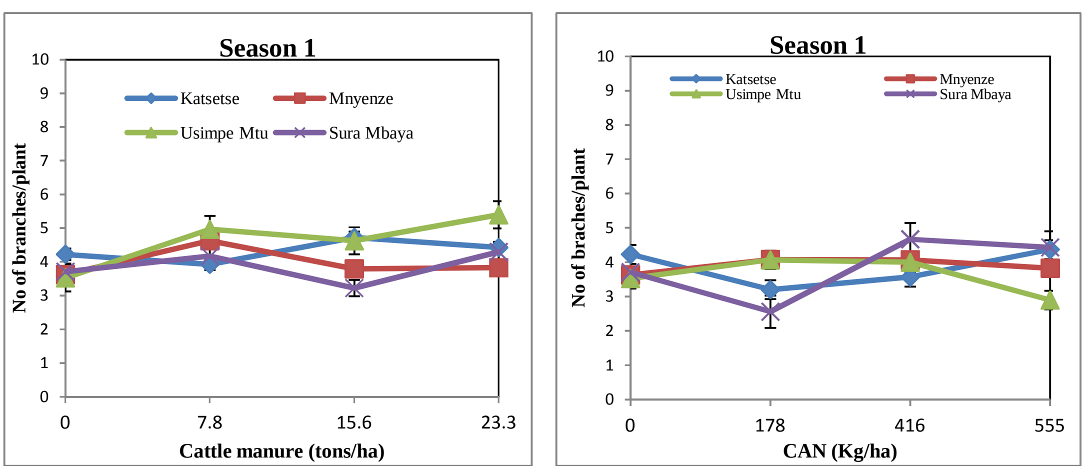

Fig. 4a. Effect of cattle manure and calcium ammonium nitrate (CAN) on the number of branches/plant of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

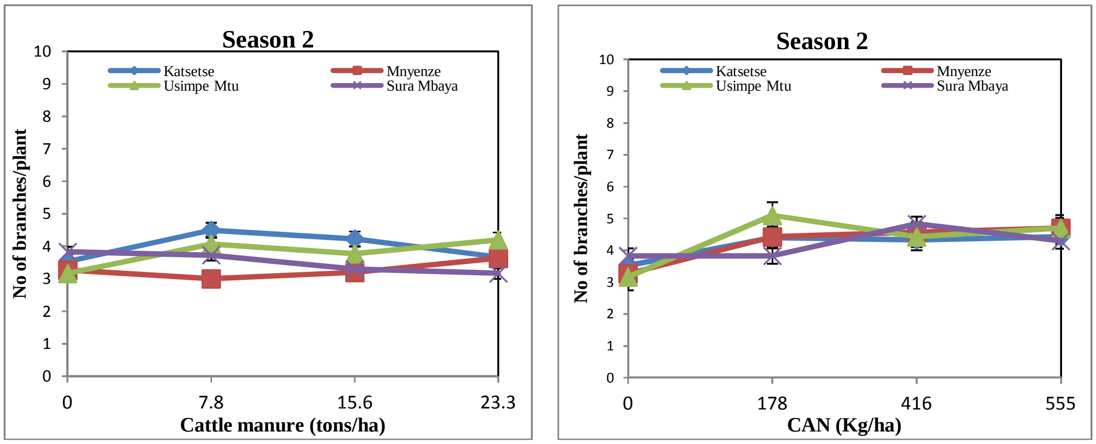

Fig. 4b. Effect of cattle manure and calcium ammonium nitrate (CAN) on the number of branches/plant of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

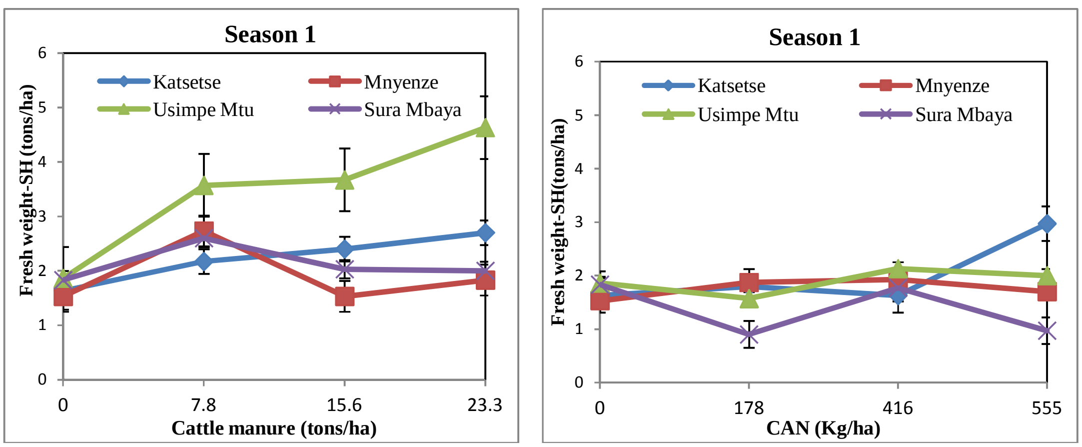

Fig. 5a. Effect of cattle manure and calcium ammonium nitrate (CAN) on Fresh weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

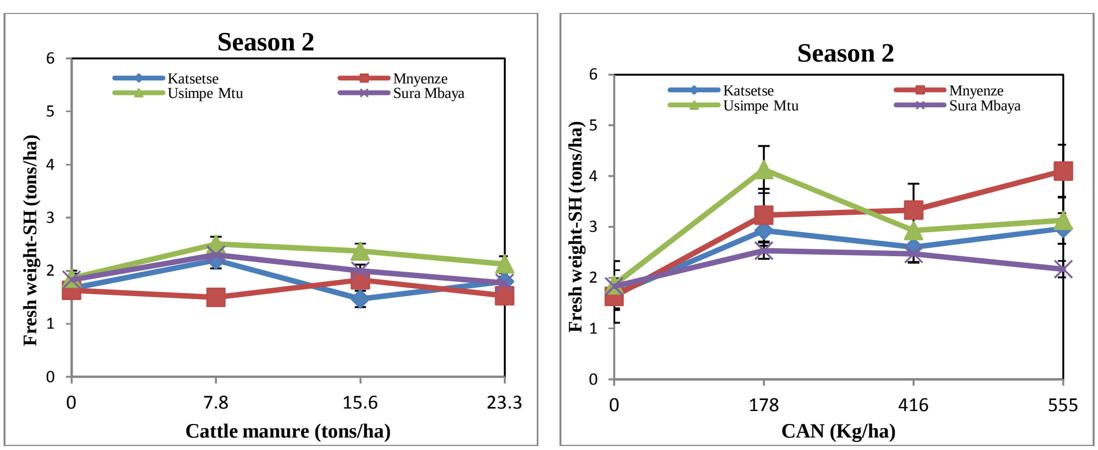

Fig. 5b. Effect of cattle manure and calcium ammonium nitrate (CAN) on Fresh weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

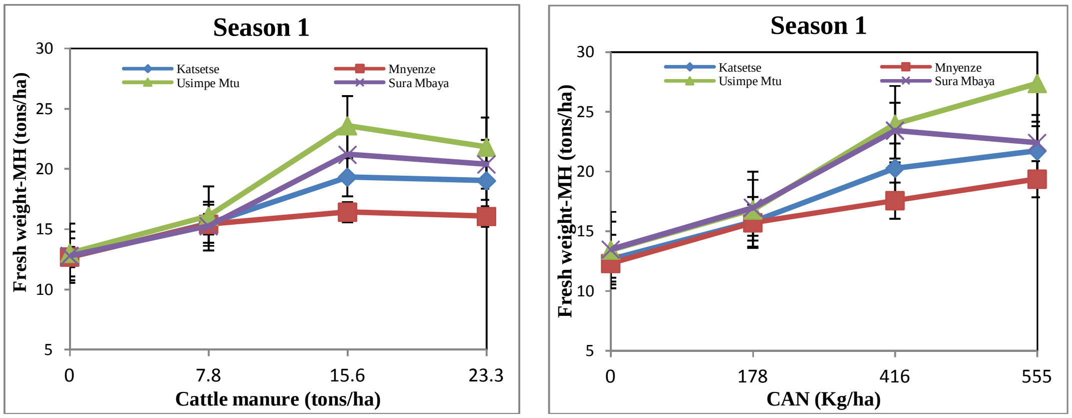

Fig. 6a. Effect of cattle manure and Calcium ammonium nitrate (CAN) on fresh weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi County in Season 1 (I = standard error at *P*=.05)

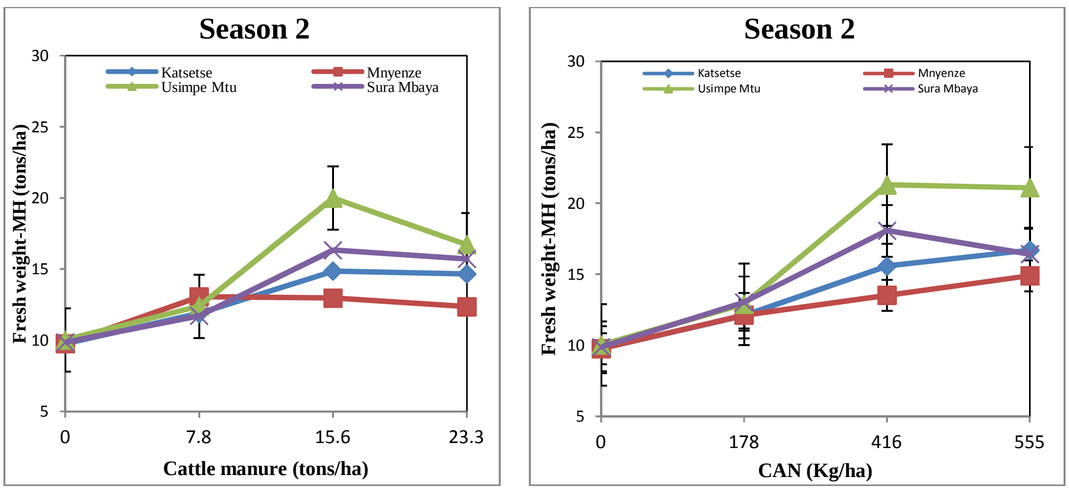

Fig. 6b. Effect of cattle manure and calcium ammonium nitrate (CAN) on fresh weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

The dry weights of harvested cowpea leaves of the local accessions tested showed similar trends as the fresh weights (Figs. 7 and 8) with multiple harvesting doubling the yields. The dry matter leaf yields were higher for those grown in season 1 than those in season 2 (Figs. 7 and 8). Similar trends were been reported in Morogoro, Tanzania where application of 8t/ha of both poultry and goat manures poultry and goat manure increased plant height cowpeas [9]. Another study in Sri Lanka showed that high cowpeas leaf yields were obtained through application of poultry manure combined with recommended rate of inorganic fertilizer [10] although goat and cattle manure were inferior to poultry manure. It is however important to note that cowpea may not require a lot of nitrogen fertilizer because it fixes its own nitrogen using the nodules in its roots. There is a possibility that low response of the local cowpea accessions could have resulted from higher nodulation and corresponding nitrogen fixation [18] although cropping systems had no effects on nodule number and nodule weight [19].

Some commercial farmers often harvest their cowpea once by uprooting the entire crop. The results from the present study indicate that multiple harvests increase cumulative yields and improve general plant growth and development. In a study conducted in Swaziland where the effects of nitrogen application and leaf harvesting frequency were investigated, it was found that additional nitrogen increased seed yield [17]. The seasonal fluctuations on yield suggest the need to investigate optional management practices to enhance incomes and cowpea availability throughout the year.

Current consumer preference is for organically grown produce because they are free from toxic residues and have concern for environment and the current study indicates that depending on the season, cattle manure can promote higher yields than inorganic fertilizer.

The increased yield due to P addition may be attributed to increased leaf area, plant height and increased branching [20]. Animal manure is a good source of organic matter in the soil and helps to improve chemical, physical and biological properties of the soil and is also a source of energy in the soil ecosystem. They can increase the water holding capacity of the soil and the cation exchange capacity [21] and are an important and cheaper source of N for crop production than inorganic fertilizers such as CAN. Inorganic fertilizers could, however provide quicker supply of nutrients for commercial farmers even during the dry seasons when water availability is scarce.

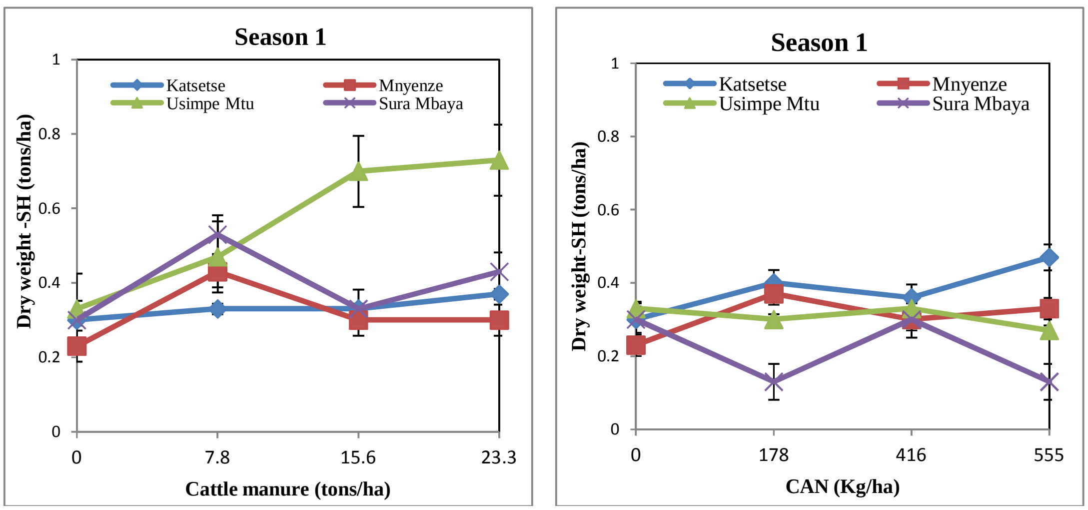

Fig. 7a. Effect of cattle manure and calcium ammonium nitrate (CAN) on dry weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

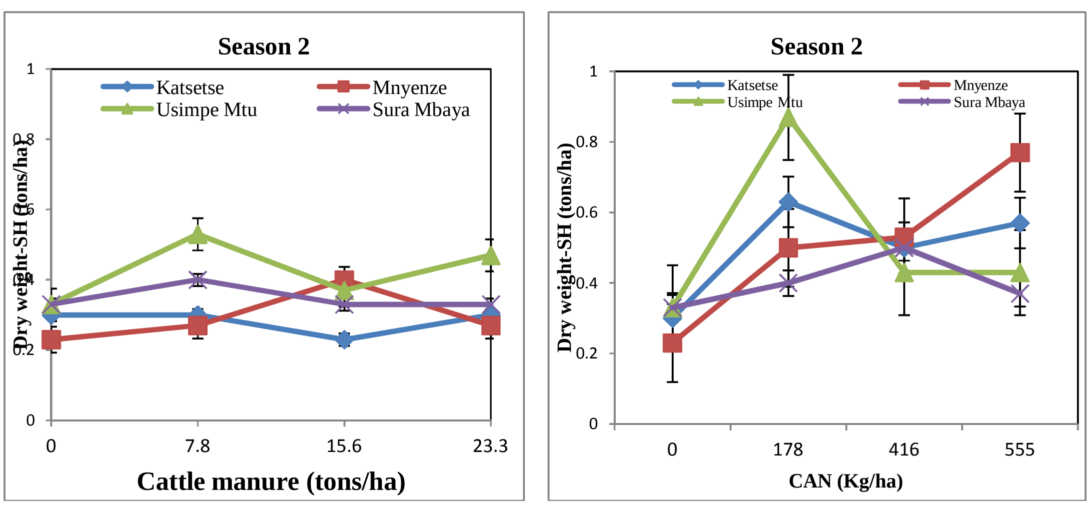

Fig. 7b. Effect of cattle manure and calcium ammonium nitrate (CAN) on dry weight (tons/ha) on single harvest of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

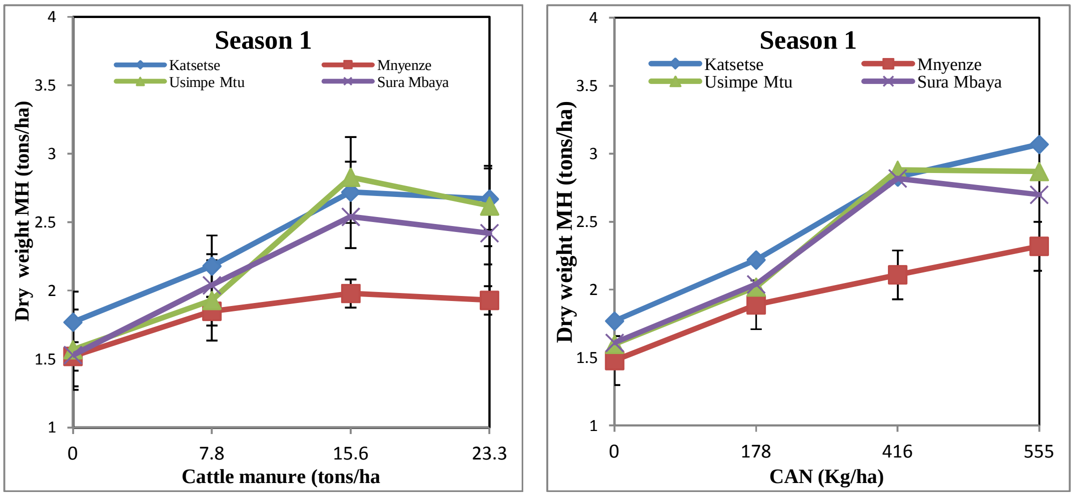

Fig. 8a. Effect of cattle manure and calcium ammonium nitrate (CAN) on dry weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi county in season 1 (I = standard error at *P*=.05)

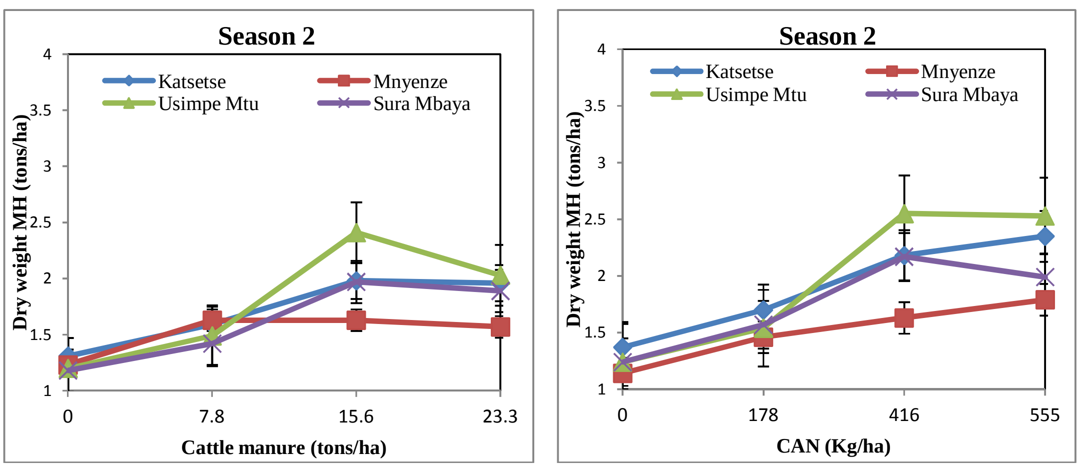

Fig. 8b. Effect of cattle manure and calcium ammonium nitrate (CAN) on dry weight (tons/ha) on multiple harvest of four local cowpeas accessions in Kilifi county in season 2 (I = standard error at *P*=.05)

4. CONCLUSIONS

In conclusion, the current results indicate that incorporation of about 15.6 tons/ha of cattle manure and 416 kg/ha CAN was optimum for improved growth and leaf yield of the four tested local cowpea accessions in coastal Kenya. The four popular cowpea accessions tested were quite comparable with Usimpe mtu mdogo and Katsetse being slightly more responsive to organic and inorganic fertilizers and therefore hold greater potential to providing food security. The use of organic amendments in agriculture has increased over the years, due to the increasing cost of inorganic fertilizers and high demand for quality and uncontaminated products. Organic fertilizers, when available, are cheaper and could provide feasible alternatives for resource poor farmers, especially women as the crop is still regarded as a women's crop.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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