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Influence of *Mucuna pruriens* Green Manure, NPK and Chicken Manure Amendments on Soil Physico – Chemical Properties and Growth and Yield of Carrot (*Daucus carota L.*)

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Abstract. Field experiments were conducted during the 2010 and 2011 growing seasons at the University of Education, Winneba, Mampong-Ashanti campus, located in the forest-savanna transitional zone of Ghana. The study evaluated the influence of *Mucuna pruriens* (MP) green manure, NPK (15:15:15) and chicken manure (CM) or their combinations on soil physical and chemical properties; and growth and yield of carrot. The six treatments, which were arranged in a RCBD included: 250 kg NPK ha^{-1}, 20t CM ha^{-1}, 30t MP ha^{-1}, 125kg NPK ha^{-1} + 15t MP ha^{-1}, 10t CM ha^{-1} + 15t MP ha^{-1} and no amendment (control). The application of MP green manure, CM, MP + CM, and MP + NPK fertilizer combinations significantly improved soil total porosity and gravimetric moisture content than the control. Soil bulk density was high in the control plots than the manures and their combinations with NPK. Compared with the control, the application of CM, MP green manure, NPK + MP and CM + MP significantly increased soil organic carbon, N, P, K, Ca, Mg, ECEC and percentage base saturation levels. Organic matter content, NH^{+}_{4}-N, NO^{-}_{3}-N and SO^{2-}_{4}-S were high in the amended plots than the control. Plant height, number of leaves per plant and canopy spread per plant for the 20t CM ha^{-1} treatment were significantly ($P<0.05$) higher than the other five treatments in both 2010 and 2011 seasons. All the amended plots produced longer carrot roots with larger diameter than the control in 2010 and 2011 seasons. The 20t CM ha^{-1} produced the highest root yields with the 10t CM ha^{-1} + 15t MP ha^{-1} following as the second highest in the 2010 and 2011 seasons. Root yield, and harvest index for all the amended plots were significantly higher than the control. The use of *Mucuna pruriens* green manure, chicken manure and the MP + NPK as well as the MP + CM combinations are recommended for improving soil fertility and increased yield of carrot.

Keywords: *Mucuna pruriens,* Green manure, soil properties, carrot yield.

INTRODUCTION

The productivity of soils under long-term crop production in Ghana has been declining over the years, a challenge also experienced in most developing countries (Kang *et al*., 1990). Although high crop yields, can be obtained with judicious use of inorganic fertilizers, agriculture with high chemical inputs has not been widely adopted in the humid and sub-humid tropical Africa. Various factors that have accounted for the low use of fertilizers include, low income levels of farmers and the increasing costs of fertilizers (Tian *et al*., 1993; Buckles *et al*., 1998). Furthermore, heavy reliance on inorganic fertilizers tend to favour farmers with large hectares of land (Meelu *et al*., 1994). Other ways to remedy nutrient deficiency and declining soil productivity are to explore natural sources of fertilizers (Gyamfi *et al*., 2001). Among the natural sources are, farmyard manure, compost and green manures. In Ghana, there is relative abundance of farmyard manure in the urban and peri-urban areas, however, the use of farmyard manure and compost has some transportation and storage problems. The more readily available green manures from leguminous crops therefore constitute a valuable potential source of N and organic manure (Meelu *et al*., 1994), which benefits have not been extensively exploited.

Evans *et al*. (1983) indicated that the use of green manure by small-scale farmers in developing countries would not only increase crop yield many folds, but would also improve the physical and chemical properties of the soils with minimum environmental risk.

Canavalia ensiformis is one of the effective green manure crops in the rain forest and forest-savanna transition zones of Ghana and is ranked second to *Mucuna pruriens* among a number of cover crop and green manure species preferred by farmers (Gyamfi *et al*., 2001). *Mucuna pruriens* has been used as a cover crop to increase maize yields (SFSP, 2000) and as a green manure crop (Agyenim-Boateng and Peprah, 2001). *Pueraria* and *Mucuna* are the most commonly used legumes to maintain or improve soil fertility and to control erosion (Wilson and Lal, 1986).

Responses of many crops to green manures have been extensively studied (Hariah and van Noordwijk, 1989; Giller and Wilson, 1991; Meelu *et al.*, 1994; Becker and Johnson, 1989; Agyenim-Boateng and Peprah, 2001). However, few vegetable crops such as carrot have been tested with green manures in general and *Mucuna pruriens* in particular. The objective of this study was to evaluate the influence of *Mucuna pruriens* green manure, NPK and chicken manure amendments on soil physico-chemical properties, growth and yield of carrot (*Daucus carota* L.)

MATERIALS AND METHODS

Field experiments were conducted at the Multi-purpose crop nursery research field of the College of Agriculture Education, University of Education, Winneba, Mampong-Ashanti campus from July to December, 2010 and March to August, 2011. Mampong Ashanti is located in the forest-savanna transition agro ecological zone of Ghana. The area has a bimodal rainfall pattern with the major rainy season occurring from March to July and the minor rainy season from mid-August to November. There is a harmattan (dry season) from December to February. The soils belong to the Bediase series of the savanna ochrosol, which are deep red sandy-loam, well drained with pH of 5.5 – 6.5; and are classified as Chromic luvisol according to the FAO/UNESCO legend (Asiamah, 1988).

A randomized complete block design with four replications and six treatments was used. The treatments were: 250kg NPK(15-15-15) ha^{-1}, 20t ha^{-1} chicken manure (CM), 30t ha^{-1} *Mucuna pruriens* (MP), 125kg NPK ha^{-1} + 15t MP ha^{-1}, 10t CM ha^{-1} + 15t MP ha^{-1} and no amendment (control). Each plot measured 4m x 2m. Four beds were raised in each plot and each bed measured 2m × 1.5m. The *Mucuna pruriens* and well-decomposed chicken manure were incorporated into the soil (0-15cm) for three weeks before the beds on which the carrots were planted were raised.

Seeds of an improved carrot variety (Kuroda) were sown by drilling to a depth of about 2 cm and at 25 cm between rows on each bed for both the 2010 and 2011 season experiments. The beds were shaded with palm fronds and watered. Germination was observed five to seven days after sowing and a shed was raised to provide light shade over the young seedlings. The seedlings were thinned 21 days after germination to intra-row spacing of about 10 cm. Weed control was by hand-picking with the aid of a hand fork. Beds were regularly kept in shape by earthing-up to check exposure of underground parts of the crop. The inter-row spaces were stirred up with hand fork at two weeks intervals to improve aeration and enhance growth of the crop.

Ten plants were randomly selected from the two middle rows and tagged for record taking. Plant height, number of leaves per plant and canopy spread were taken at 4, 6, 8 and 10 weeks after sowing. Root length and root diameter at 2 cm from the top were measured after harvest. Yield of the roots from each plot was weighed with an electronic balance.

The data were analyzed using the SAS package.

RESULTS AND DISCUSSION

Initial Soil Chemical Properties

The initial chemical properties of the soil taken are presented in Table 1. The results indicated that the soil was acidic (pH 4.5). The organic matter content level was moderate, the percentage N is less than 0.15% and not considered optimum for the growth of carrot and other vegetables (Odedina *et al*., 2007). The soil P is considered optimum for crops, while K, Ca, and Mg had values which were critical levels considered adequate for vegetables (Meelu *et al*., 1994).

Table 1: Initial soil chemical properties (0-20 cm depth) at the experimental site

Chemical properties	Value
pH (H_2O 1:1)	4.50
Org. C%	0.90
Organic M%	1.55
Total N%	0.09
Exch. Cations (me/100g)	
Ca	2.12
Mg	1.07
K	0.34
Na	0.07
T.E.B	2.67
Exch. A (Al + H)	0.50
ECEC me/100g	1.89
% Base saturation	69.98
Available P (ppm)	54.61
Available K (ppm)	63.60

Effect of amendments on soil chemical property

All the amended plots showed higher increase in all the nutrient levels than the control treatment (Table 2). The manure treated plots and their combinations recorded higher levels of organic carbon, percentage total nitrogen, and organic matter than the NPK alone. The manure application influenced the soil pH (Table 2). This study clearly indicates that soil acidity has been reduced. The increase in pH from 4.5 in the control treatment to between 5.10 - 6.36 in all the amended plots might be due to the addition of organic matter to the soil and thus affirming the findings by of Magdoff (1988) and Tisdale *et al.* (1990) that organic matter adds basic plant nutrients to the soil which may increase the pH of the soil.

The addition of *Mucuna pruriens* and chicken manure to the soil might have provided supplemental nutrients such as K, Ca, Mg, NO_3^- and NH_4^+ in the top soil. The cation exchange capacity levels increased due to the manure application. This agrees with the work done by Magdoff (1988) and Frempong *et al.* (2006), that addition of organic manure increases organic matter content which in turn increases the levels of Ca, K and Mg. Similarly Grichs (1990) indicated that the application of organic manure increased organic carbon, NPK, Ca and Mg than soil amended with inorganic fertilizer (NPK) alone, and the increase was assigned to the high organic carbon content of the organic manure.

Eghball *et al.* (2002) reported significantly greater soil organic matter levels in plots treated with organic manure. In the present study, the combination of *Mucuna pruriens* and chicken manure gave the highest organic matter content followed by the sole chicken manure and the sole *Mucuna pruriens* treatment.

Table 2. Effects of amendments on nutrient levels and chemical characteristics of soil after decomposition

Treatments (ha-1)	pH H_2O 1:1	Org. % C	Total % N	Org. % M	Exch. Cations (me/100g)				T.E.B.	Exch. A (Al + H)	ECEC me/100g	% Base sat.	Available Bray's		NH_4^+- N mg/kg	NO_3 – N mg/kg	SO_4^{2-} - S mg/kg
					Ca	Mg	K	Na					P(ppm)	K(ppm)			
No amendment (Control)	4.50	0.90	0.09	1.55	2.11	1.07	0.34	0.07	2.77	0.50	1.89	69.98	54.61	63.60	2.88	3.11	6.75
250kg NPK	5.10	1.36	0.13	2.72	3.50	1.34	0.54	0.11	5.19	0.65	5.84	88.87	112.50	170.4	520.08	28.00	64.50
20t CM	6.36	1.85	0.17	3.20	5.77	1.50	1.00	0.74	9.01	0.60	9.61	93.75	415.81	231.00	41.23	57.33	11.00
30t MP	5.55	1.81	0.16	3.12	3.95	0.91	0.48	0.40	5.14	0.80	5.94	86.53	70.18	103.78	256.00	40.89	12.00
125kg NPK + 15t MP	5.85	1.73	0.14	2.98	3.95	0.85	0.43	0.44	5.67	1.00	6.67	85.00	67.07	110.78	531.69	103.11	69.25
10t CM + 15t MP	6.21	1.88	0.15	3.24	4.43	1.12	0.57	0.52	6.64	0.80	7.44	89.24	150.76	143.76	13.85	37.33	12.75
LSD (0.05)	0.05	0.02	0.01	0.03	0.02	0.01	0.06	0.75	0.1	0.01	0.01	0.01	0.06	0.08	0.28	0.25	0.22
CV (%)	0.07	0.07	6.80	0.70	0.30	0.80	7.60	15.84	0.2	0.90	0.10	3.10	6.50	5.40	0.10	0.40	0.50

Effect of amendments on soil physical characteristics

The bulk density of the chicken manure and *Mucuna pruriens* green manure treatment combinations recorded lower bulk density than the sole NPK treatment. The low bulk density might have favourable impact on soil water holding capacity and infiltration (Akanini, 2005). The control treatment gave the highest bulk density among all the treatments. However, all the amended plots recorded lower bulk density than the control (Table 3).

The 250kg NPK ha^{-1} treatment gave the lowest total porosity among the amended plots, while the 125kg NPK ha^{-1} + 15t MP ha^{-1} treatment gave the highest among all the treatments. However, all the amended plots had higher total porosity than the control (Table 3). The 30t MP ha^{-1} treatment gave the highest gravimetric moisture content among the treatments. Among the amended plots, the 250kg NPK ha^{-1} treatment gave the lowest value of the gravimetric moisture. The application of the organic manures improved the soil's physical properties. The improved soil water content is attributed to the mulching effect of organic manure and improved moisture retention and water acceptance as a result of improved soil structure and macro-porosity (Aluko and Oyedele, 2005), and also it might be due to the colloidal and hydrophobic nature of the manure (Aluko and Oyedele, 2005).

The influence of organic manure application in improving the soil physical conditions had been widely reported (Akanni, 2005). The improvement in the soil's physical properties with the application of chicken manure and *Mucuna pruriens* green manure is attributed to the increase in soil organic matter from the manure (Adenawoola and Adejoro, 2005).

Table 3: Soil physical properties at the experimental site after the decomposition of the soil amendments

Treatments (ha^{-1})	Bulk Density (g/cm^3)	Total Porosity (%)	Gravimetric Moisture Content (%)
No amendment (Control)	1.50	43.20	10.40
250kg NPK	1.39	46.10	11.65
20t CM	1.34	48.62	12.60
30t MP	1.33	50.10	14.00
125kg NPK +15t MP	1.36	52.20	12.70
10t CM +15t MP	1.32	51.70	13.20
LSD (0.05)	0.01	0.13	0.12
CV (%)	2.33	3.20	2.95

Vegetative growth of carrot

In both seasons, the manured plots produced plants with significantly higher number of leaves than the control (Fig.1). The significant increase in the number of leaves of carrots recorded from the soil treated with *Mucuna pruriens* green manure and chicken manure as compared to the control might be due to the high nitrogen and presence of exchangeable cations in both manures. According to Wolf (1997), adequate amounts of nitrogen may be obtained from reasonable amounts of organic matter applied to the soil and it is directly responsible for the vegetative growth of plants. The number of leaves per plant are relevant to canopy development and closure, which is significant for the interception of solar radiation, dry matter accumulation and partitioning (Evers, 1988).

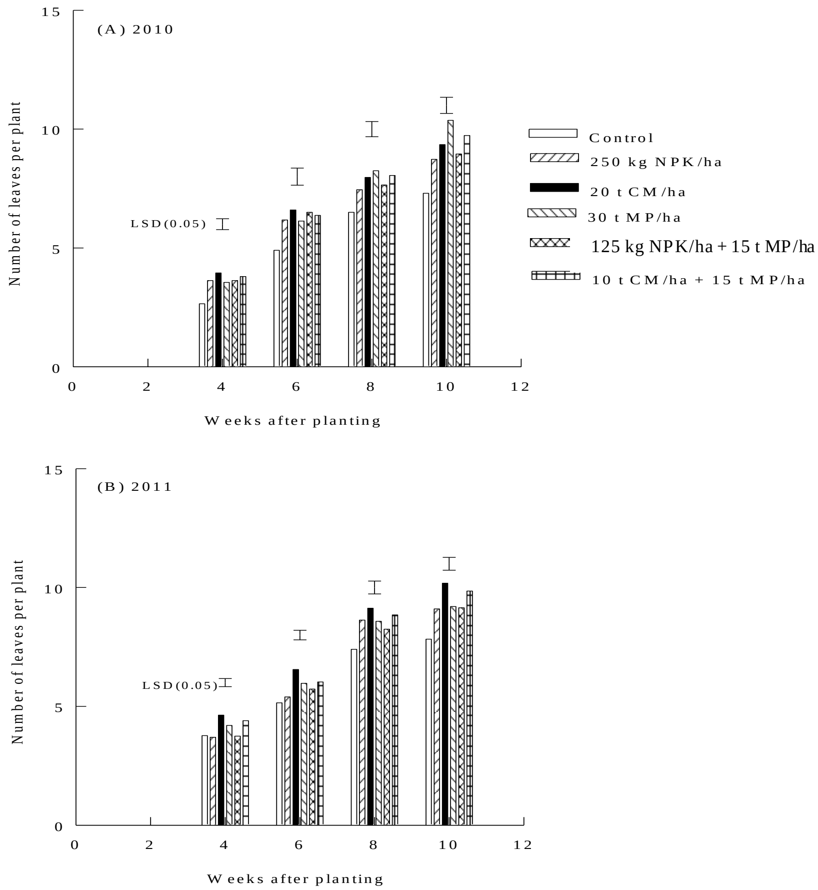

Fig.1: Number of leaves per plant of carrots as influenced by soil amendments in the (A) 2010 and (B) 2011 seasons.

The amended plots also produced taller plants than plants from the control plots in both seasons (Fig. 2). Plots amended with chicken manure and the *Mucuna pruriens* green manure produced the tallest carrot plants. Generally, all the amended plots did not show any significant ($P<0.05$) difference among them from 7WAP to 10WAP in the 2010 season. However, in the 2011 season, the sole chicken manure (20t CM ha^{-1}) treatment produced the tallest plant throughout the growing period and was significantly ($P<0.05$) higher than all the amended plots and the control (Fig. 2.b). This might be due to the higher nitrogen, phosphorus and potassium contents that were involved in plant growth, respiration and energy storage and rapid shoot growth. This agrees with Blay *et al*. (2001), who reported that the application of organic fertilizers to the soil supply plant nutrients for increased plant height and more leaves in shallots.

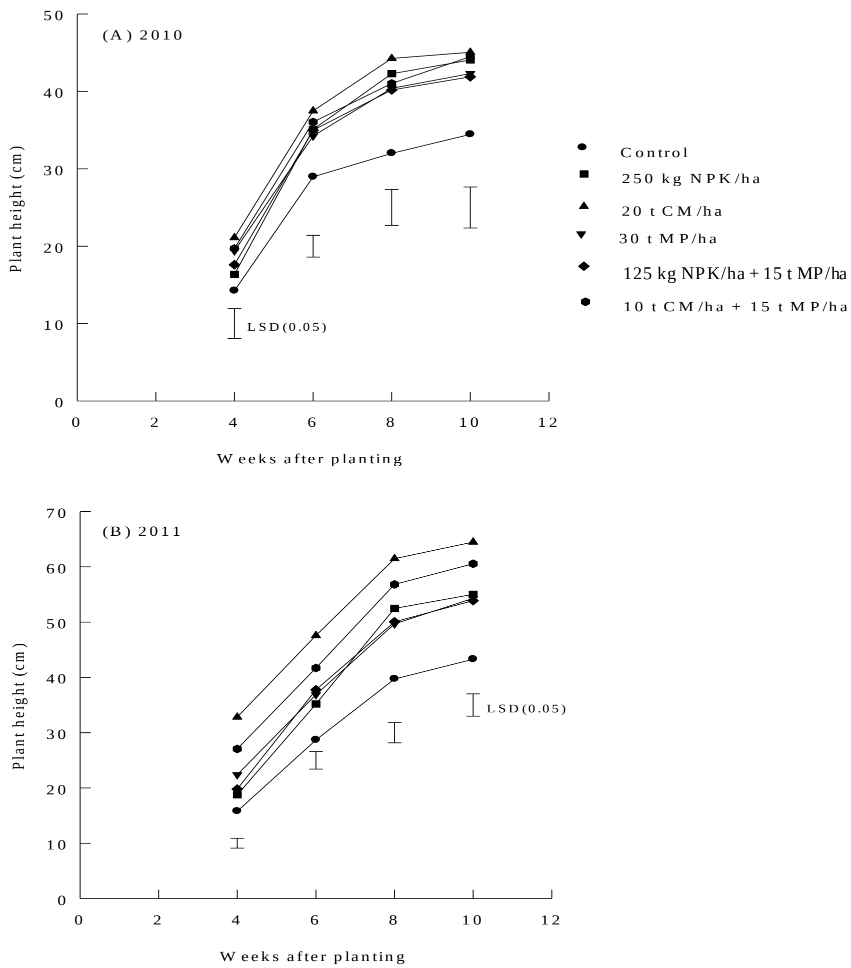

Fig. 2: Plant height of carrot as influenced by soil amendments in (A) 2010 and (B) 2011 seasons.

The mean canopy spread of leaves of carrot plants for all amended plots was higher than the control (Fig 3). The sole chicken manure treatment had the highest canopy spread and this was followed by the combination of *Mucuna pruriens* and chicken manure treatment. Difference in the canopy spread with *Mucuna pruriens* green manure treatment was significant (P<0.05) at 8WAP. The high vegetative growth of carrots from the *Mucuna pruriens* green manure treatment could be due probably to the higher amount of total nitrogen fixed by the legume and increased organic matter in the soil. Allison (1973) observed that the major benefit obtained from legume green manure is the addition of organic matter to the soil. The increased number of leaves per plant might have contributed significantly to the high canopy spread of leaves and increased solar radiation interception and plant height of carrot plants grown on the amended plot (Evers, 1988).

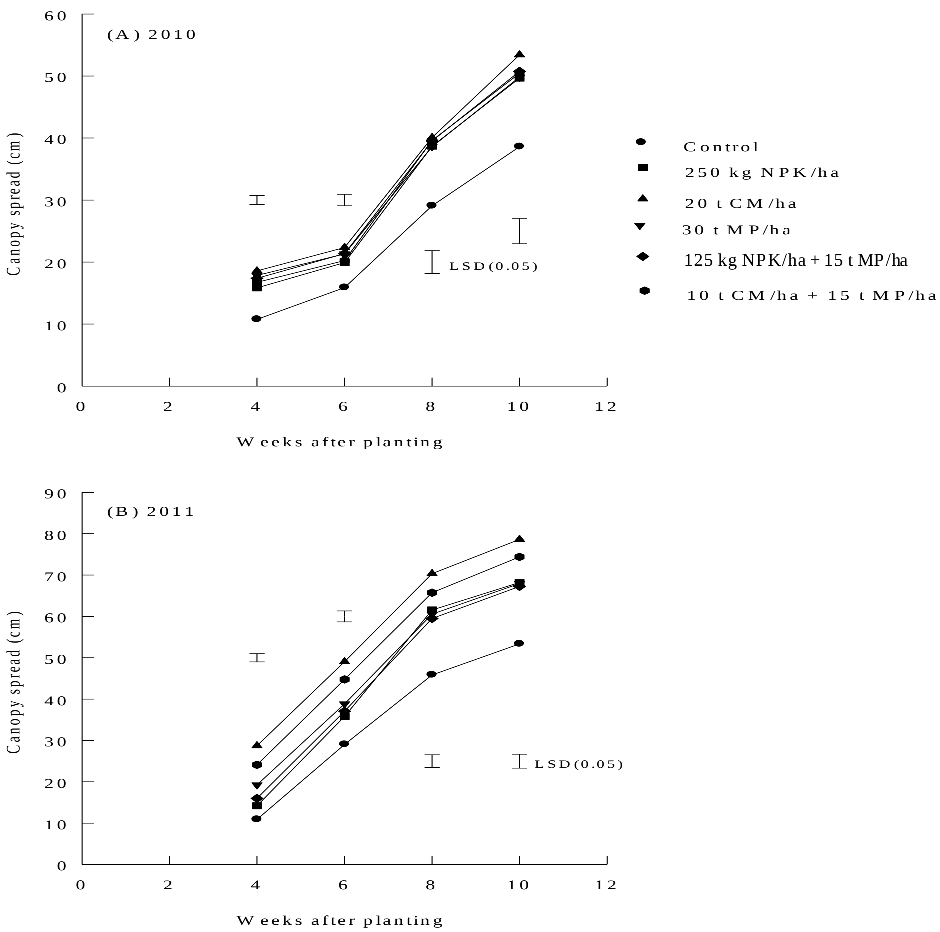

Fig. 3: Canopy spread of carrot as influenced by soil amendments in (A) 2010 and (B) 2011 seasons.

Yield components of carrot

Carrots grown on all the amended plots had significantly longer root length than carrots on the control plots in 2010 (Table 4).The 30t MP ha^{-1} plot had the highest mean carrot root length among all the amendments, but was not significantly ($P<0.05$) different. In the 2011 season, the combination of chicken manure and *Mucuna pruriens* green manure (10t CM ha^{-1} + 15t MP ha^{-1}) had the longest root length of 15.33cm, followed by the sole chicken manure (15.25cm). All the amended plots also produced significantly ($P<0.05$) longer carrot root length (about 23% more longer) than the control (Table 4).

On the average the mean carrot root diameters on the amended plots were significantly ($P<0.05$) higher than the unamended plots in both 2010 and 2011 seasons (Table 4). The sole chicken manure treatment produced the largest carrot root diameter (Table 4). The significant differences in carrot root length and girth (diameter) in manured plots compared to the control might be due to differences in soil structure and fertility - the increase in water holding capacity, NO_3^--N, N, P, K, Ca and Mg and presence of micro nutrients in chicken manure and *Mucuna pruriens* green manure provided some advantage (Agyarko *et al.*, 2006; Frempong *et al.*, 2006 and Ewulo *et al.*, 2008).

Table 4: Yield components of carrots as influenced by soil amendments in 2010 and 2011 growing seasons.

Treatments (ha^{-1})	Root Length (cm)		Root Diameter (cm)		Fresh Root Yield (t/ha)		Harvest Index	
	2010	2011	2010	2011	2010	2011	2010	2011
No amendment (control)	9.25	12.03	2.12	2.83	3.50	6.18	0.26	0.41
250kg NPK	12.37	13.65	2.95	4.03	6.37	9.90	0.36	0.56
20t CM	12.85	15.25	3.22	4.37	6.85	14.65	0.40	0.55
30t MP	12.97	14.88	2.87	3.92	6.67	10.75	0.38	0.55
125kg NPK + 15t MP	12.72	14.90	2.90	3.97	6.75	11.20	0.37	0.58
10t CM + 15t MP	12.50	15.33	3.15	4.27	6.45	13.45	0.37	0.55
LSD (0.05)	1.23	0.74	0.29	0.25	0.56	0.99	0.01	0.01
CV (%)	6.80	3.40	6.70	4.30	6.20	6.00	1.90	1.50

Fresh carrot root weight was significantly similar for all the soil amendments and ranged from 6.37-6.85t ha^{-1} for the 2010 season (Table 4). However, the 20t CM ha^{-1} recorded significantly the highest root yield (14.65t ha^{-1}) in 2011 season. All the amended plots recorded significantly higher root yield than the control in both seasons. The amended plots had carrot roots that were longer and bigger than the control plot and might have accounted significantly for the higher root yields of the amended treatments than the control treatment (Adeniyan and Ojeniyi , 2005).

Carrots grown on sole chicken manure soils (20t CM ha^{-1}) generally produced the highest yields and the sole NPK (250 kg NPK ha^{-1}) the lowest/ least yields in both seasons among the amended plots. The integrated combination of CM + MP recorded the second highest yield value. The sole chicken manure applied soils produced slightly bigger and longer carrot fresh roots than the other amended plots, and thus might have contributed to the slight edge in yield over the other amendments (Agyarko *et al.*, 2006).

Harvest index for carrot roots did not differ among the soil amendments and ranged from 0.37-0.40 and 0.55-0.58 compared with 0.26 and 0.41 for the control for the 2010 and 2011 growing seasons, respectively. Harvest index (a dry matter partitioning coefficient or distribution index) indicates the level of efficiency that the dry matter produced by the crop is partitioned or distributed into the economically important parts of the crop (in this case the root) (Evers, 1988). The carrots grown on amended soils were therefore more efficient in distributing or partitioning dry matter into the economic root part than the control.

The yield and other yield characteristics of carrot improved significantly with the application of the amendments (Tables 4), which followed the pattern of the changes in the nutrient levels in the soil after treatment application. Similar findings were obtained by Agyarko *et al*. (2006) that yield and yield characteristics of carrot improved in relation to rising levels of amendments and tend to be affected by increasing soil nutrients. The increase in yield recorded by the manures and the integrated combinations might have been due to the improvement of the physical structure of the soil and the nutrients supplied as stated by Dennis *et al*. (1993) and Frempong *et al.* (2006). The addition of organic amendments increased the total porosity which decreased the bulk density and thereby increasing root penetrability. This improved nutrient exploration by plants for better growth and yield (Meelu *et al*., 1994)

Conclusion

The study showed that the application of *Mucuna pruriens* green manure, chicken manure or their integrated combinations used as amendments increased soil organic matter content as well as increase in soil nutrients such as P and K, total N and ECEC.

The application of *Mucuna pruriens* green manure and chicken manure promoted plant growth and improved yield of carrot compared to no form of amendment. With the yield components, the sole *Mucuna pruriens* green manure and chicken manure performed better in terms of carrot root length and root girth (diameter) in 2010 season, while the combination of chicken manure and *Mucuna pruriens* recorded the highest root length in 2011 season. However, the sole chicken manure recorded the highest root yield in both 2010 and 2011 season and this was closely followed by the combined treatment of chicken manure and *Mucuna pruriens*.

The application of organic manure improved the physical attributes of the soil. Gravimetric moisture content and total porosity of the soil increased while bulk density was reduced. The *Mucuna pruriens* green manure, chicken manure or their integrated combination treatments were more effective than the rest of the amendments with respect to improving soil physical and chemical conditions, plant growth and yield of the crop. Therefore, this is recommended for further or extensive evaluation on farmers' fields for possible adoption.

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