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N-Credits from Different Maturing Cowpea Varieties to Carrot in Rotation

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Abstract

Legumes constitute a major component of sustainable cropping systems due to their biological nitrogen fixing potential. A field study was conducted in 2020 and 2021 at Ashanti-Mampong in the forest transition zone of Ghana to quantify nitrogen credits to carrot from early (70 - 75 days) and medium maturing (80 - 85 days) cowpea varieties (Asetenapa and Soronko) respectively, and Obatanpa maize variety as a reference crop. The experimental design was a split plot with five Nitrogen levels (0, 30, 45, 60 and 90 N kg/ha) applied to carrot as sub-plots following the legumes and the maize variety as main plots. NPK (15:15:15) was applied at the rate of 250 kg/ha to provide the nitrogen. The sub-plot treatments (0, 30, 45, 60 and 90 N kg/ha) were planted following the two cowpea varieties and the maize variety as a reference crop. Soronko had the highest number of nodules (176) while Asetenapa had the lowest nodules (55). Nitrogen credit to carrot from the early-maturing cowpea (Asetenapa) was 32 N kg/ha in the first year of incorporation and 18 N kg/ha in the second year after incorporation. N-credit from the medium-maturing cowpea (Soronko) was 18 N kg/ha and 29 N kg/ha in the first and second year after incorporation respectively. Obatanpa maize variety with 0 kg N/ha fertilizer level produced the lowest carrot yield, indicating that the soil amendment increased yields. The species and maturity of legumes are important determinants of their N credit contribution to crops in rotation.

Keywords

N-Credit, Sustainable, Cropping Systems, Incorporation, Nitrogen Fixation

1. Introduction

Vegetables are important dietary sources of nitrate for human nutrition. Vegetable production is an important crop sub-sector of Ghana's agriculture with a great potential for both local and international markets. Over the past decades, Global production figures show that vegetable production has increased from 682.43 million in 2000 to 1.09434 billion metric tons in 2017 [1]. Even though this increment has contributed significantly to consumption, employment and income needs of many people globally, vegetable production levels in Ghana and Africa remain woefully low and unable to meet local market demands. This low production has been attributed poor soil fertility [2] as well as farmers' inability to use fertilizers appropriately and optimally due to poor access to and inefficient management of inputs [3].

Carrot is a valued exotic vegetable in Ghana, mostly used in combination with other vegetables in preparing soups, stews, salads and drinks. Its production can be a lucrative farming activity since it is a short duration crop and can result in higher yields per unit area [4]. Ashanti Mampong Municipality in the Ashanti Region of Ghana is among the leading producers of vegetables in general and carrots in particular in Ghana. Demand for carrots remains high especially in the nearby urban centres such as Kumasi and Techiman. While production statistics of carrot is yet to be officially documented for Ghana [5], its production levels and yield per unit area remain low [6].

One of the factors that cause low yield of carrot in Ghana is poor soil fertility. The nutrient status of the soils is highly depleted because of factors such as continues cropping as well as diminutive mineral and organic fertilizer use by resource poor farmers [7]. Cropping cowpea generally improves soil fertility through nitrogen fixation and addition of soil organic matter. It compensates for the loss of nitrogen absorbed by cereals and has a positive impact on soil properties. This is due to its unique capacity to fix atmospheric nitrogen and good performance even in poor soils. The total nitrogen fixation in the world is estimated to be about 1.75×10^{11} Kg, of which symbiotic nitrogen fixation in legumes accounts for about 8.0×10^{10} Kg by fixing, on average, 20 - 200 kg N fixed ha^{-1} $year^{-1}$, and the other near half is industrially fixed while producing N fertilizers (about 8.8×10^{10} Kg) [8]. Biological nitrogen fixation (BNF) through rhizobia-legume symbiosis is, thus, the best alternative and a more sustainable process by a group of symbiotic bacteria, so-called rhizobia, which fix the atmospheric nitrogen and make the fixed nutrient available to the host legume and other crops in the cropping system [9].

Smallholder farmers in the carrot production areas in the Ashanti Mampong Municipality generally experience high production costs mainly due to application of inorganic fertilizers. In addition, the application of inorganic fertilizers has adverse and unpredictable problems in the environment. Consequently, the use of legumes such as cowpea for nitrogen fixation leading to soil fertility enhancement provides a viable alternative for sustainable crop production [9] [10]. This practice, apart from restoring soil fertility, breaks the cycles of diseases and pests that attack crops [11]. Full utilization of BNF and optimal benefit from BNF systems can be recognized through integrating legumes such as cowpea into agricultural systems in which the benefits of BNF can be extended to crops and cropping systems [9] [11]. The common practices of integrating legumes into cropping systems include crop rotation, simultaneous intercropping, improved fallows, green manuring, and alley cropping [11] [12] [13] [14]. Therefore, improvement and utilization of BNF are very important, particularly in the developing world, where much of the increases in food production must come to accommodate the increasing world population. Hence, this study examined the contribution and improvement of cowpea-based BNF in carrot production in the Ashanti Mampong Municipality in the Ashanti Region of Ghana. Specifically, the study determined the N-credits from cowpea varieties to carrots as well as the growth and yields of carrots in rotation with cowpea.

2. Materials and Methods

2.1. Experimental Site

The study was conducted at the multipurpose nursery research fields of the College of Agriculture Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong Campus, from May, 2020 to April, 2021. The preceding cowpea and maize crop were planted from May to September, 2020, the first season carrots were planted from October, 2020 to January, 2021, and the second season carrots planted from January to April, 2021. Mampong-Ashanti is at an altitude of about 435 m and is located in the forest-savanna transition zone of Ghana. It has a bimodal rainfall pattern with the major rainy season occurring from March to July, and the minor season from late August to November. There is a dry (harmattan) season from November to March. The soils at the experimental site belong to the Bediese series and are classified as Savanna Ochrosol [15].

2.2. Soil Analysis and Climatic Conditions

Soil analysis conducted on the top soil (0 - 30 cm) before the experiment indicates that the experimental site was acidic, total N was moderate, organic matter content was moderate, the exchangeable cations (me/100g) were low and effective cations exchange capacity (ECEC) was low. However, P (ppm) was high, while K (ppm) was moderate Soil analysis conducted following the amendment with two cowpea varieties (Soronko and Asetenapa) showed that the soil remained acidic, organic carbon, organic matter content, base saturation, total N and exchangeable Al+H cations level remained almost the same after the soil amendment. However, effective cations exchange capacity (ECEC) and available P (ppm) slightly increased after the amendment. The stable cations exchange capacity (CEC) indicates soil's ability to hold nutrients for crop production.

The total rainfall during the period of the second season carrots in 2021, from January to April, was 334.3 mm. 20.8˚C and 33.7˚C were the minimum and maximum temperatures recorded, while the relative humidity ranged from 35% - 96% respectively. The main plot treatments (Soronko, Asetenapa and Obatanpa) were planted from May to October, 2020.

2.3. Experimental Design

The Split-Plot Design was used for the experiment. The experimental design used was the Split-Plot Design, comprising five treatments with three replications. The main-plot consisted two cowpea varieties (Soronko and Asetenapa) and a maize variety (Obatanpa, as a reference crop) and the sub-plots consisted of five N kg/ha fertilizer levels (0, 30, 45, 60 and 90 kg N/ha). The land was cleared of debris, ploughed, and leveled for planting. The sub-plot treatments (0, 30, 45, 60 and 90 kg N/ha) were planted in two seasons. The first carrot season was planted from September, 2020 to January, 2021, while the season carrot was planted from January to April, 2021. NPK fertilizer (15:15:15) was used to supply N to the sub-plot treatments at the rate of 250 kg/ha. The additional N was supplied using sulphate of ammonia. The Soronko variety was planted at 60 cm × 20 cm, while the Asetenapa was 50 cm × 20 cm and Obatanpa maize were planted at 80 cm × 40 cm respectively. Uniform plot size of 3 m^2 was used for the sub-plots. Weeds were controlled manually when needed. Weeding was done twice manually with the hoe. The first weeding was done three weeks after sowing, while the second was done seven weeks after sowing. Cymethoate 2.5EC (Cymethoate + Dimethoate) was applied at 40 ml per 15 litres of water using a Knapsack sprayer at 30, 40 and 50 DAS to control pest in Asetenapa, and at 35, 45, 55 and 65 DAS for Soronko. The last spraying was applied to control post flowering pests. Harvesting of the of cowpea varieties was done 75 - 85 DAS, while the maize (Obatanpa) variety was harvested at 105 DAS. The harvested cowpea pods were sun-dried after threshing and winnowing. The maize cobs were also harvested and sun-dried to about 15% moisture content before being weighed. The biomass or stubble was incorporated into the soil to decompose. The sub-plot treatments (0, 30, 45, 60 and 90 kg N/ha) were applied to the planted carrot after incorporation. After the incorporation of the biomass or stubble, the land was cleared of weeds, raked, loosened and leveled after it was thoroughly watered. Beds were raised at 1.5 cm wide and 2 cm long and each of the sub-plots for the sowing of carrots. NPK (15:15:15) was applied to provide 30 kg N/ha. The additional N for the other treatment was supplied by supplying sulphate of ammonia. Weeding was done four times at 3, 5, 7 and 9 weeks after sowing. Loosening of the soil (forking) was done periodically to enhance water percolation and air circulation and also to aid carrot root development. There were no insect pest problems encountered on the field. Watering cans were used for watering in times of droughts. Data collected were analyzed using the Analysis of Variance (ANOVA) with the SAS Statistical package [16]. The means were separated by the Least Significant Difference (LSD) at 5% ($P < 0.05$) significant level. The Nitrogen Fertilizer Replacement Value (NFRV), using maize as reference was used to determine N credits to carrot. The NFRV is the N fertilizer application rate needed to produce a crop yield equal to that produced without applied N in a legume-cereal rotation [17]. This method measures the contribution of legumes to a following crop.

3. Results and Discussion

Dry matter accumulation and nodulation

Soronko cowpea variety as a preceding crop accumulated more DM than Asetenapa. Soronko is a semi-erect medium-maturing cowpea variety. Soronko had the higher number of branches it produced, which could have influenced effective interception of solar radiation and fast accumulation of assimilates for vegetative growth than the erect Asetenapa cowpea variety. The large DM accumulated by Obatanpa maize variety could be attributed to its height and leaf spread which might have intercepted more solar radiation which led to the accumulation of more assimilates for vegetative growth. Soronko cowpea variety produced more effective nodules and nodule weight than Asetenapa. This could largely be attributed to accumulation of assimilates since it produced more number of and leaves dry matter accumulation than Asetenapa (**Table 1**).

Yield and yield components of preceding crops

The number of pods per plant, number of seeds per pod, and hundred seed weight did not differ significantly between the two cowpea varieties, which could be attributed to the lack of significant differences in the number of branches, and plant height did not differ between the cowpea varieties. The varieties had similar growth patterns, and although Soronko is medium maturing, it did not significantly produce higher yield components than Asetenapa (an early maturing variety) as it usually occurs. Therefore, the non-significant differences in some of the yield components between the two cowpea varieties could be largely due to similar growth potentials. Total grain yield significantly differed between the two cowpea varieties as Soronko had the highest grain yield (793.0 kg/ha) while Asetenapa gave the lowest grain yield (365.8 kg/ha). Soronko's performance could

Table 1. Dry matter accumulation, nodulation, yield and yield components of preceding crops, 2020.

Preceding crops	Soronko	Asetenapa	LSD (0.05)
Dry biomass at 50 DAS (g/m^2)	0.67	0.51	0.8
Dry biomass at harvest (t/ha)	2.819	1.476	105
No. of effective nodule/plant	176	55	187.8
No. of non-effective nodules/plant	3	2	1.4
Dry weight of effective nodules	1.2	0.6	1.7
No. of pods per plant	11.00	9.67	10.0
No. of seeds per plant	15.00	12.00	4.3
100 seed weight	12.07	11.43	5.1
Grain yield (kg/ha)	793.0	365.8	95.3

be attributed to the high nodulation and high DM accumulated (Table 1).

Number of roots forked, cracked and nematodes infestation

The number of forked carrot roots did not show any significant differences in both carrot seasons (Table 2). This could largely be attributed to the improved soil conditions due to the cowpea amendment. [6] reported that organic soil amendments contribute macro and micro nutrients and also improve the soil structure for effective microbial activities and crop growth, increase the water holding capacity, porosity and decrease bulk density. [18] in a research conducted on growth and yield response of carrot *(Daucus carota* L.) to different rates of soil amendments and spacing in Ashanti Mampong, reported that amendments improve soil conditions such as moisture content, soil structure, texture and reduces soil compaction which normally causes forking of carrot roots. This makes the amended soil conducive for carrot growth. However, the application of fresh leguminous organic matter to the soil during cultivation is detrimental to carrot root development [6]. The number of cracked carrot roots significantly differed in the first carrot season. This could be linked to the introduction of N fertilizer. The less cracked roots might be due to the application of inorganic fertilizer as affirmed [18], that well decomposed organic matter minimizes carrot root cracking. It could also be attributed to the soil amendment which probably improved the chemical and physical conditions of the soil for

Table 2. Number of forked and cracked roots and nematodes infestation as influenced by preceding crops and N fertilizer levels in 2020 and 2021.

	No. of forked roots		No. of cracked roots		Nematodes Ratings	
	2020	2021	2020	2021	2020	2021
Variety						
Soronko	0.07	0.07	0.00	0.20	0.07	0.60
Asetenapa	0.07	0.07	0.13	0.07	0.00	0.13
Obatanpa	0.20	0.00	0.27	0.07	0.80	0.13
Mean	0.11	0.04	0.13	0.11	0.29	0.29
LSD (0.05)	0.26	0.21	0.25	0.30	0.63	0.59
Fertilizer (kg N/ha)						
0	0.11	0.00	0.33	0.00	0.33	0.44
30	0.11	0.11	0.11	0.22	0.11	0.11
45	0.11	0.11	0.11	0.11	0.56	0.33
60	0.11	0.00	0.11	0.11	0.11	0.22
90	0.11	0.00	0.00	0.11	0.22	0.33
Mean	0.11	0.04	0.13	0.11	0.29	0.29
LSD (0.05)	0.33	0.20	0.32	0.30	0.81	0.59

crop growth. Forking is a known problem in carrot production and if the organic matter is well decomposed forking will be reduced [6]. Working the soil thoroughly into the soil for effective decomposition might have contributed to less cracking of carrot roots [6]. However, nematodes ratings recorded significant differences with the non-amended Obatanpa maize plots, while carrots grown on the cowpea crop varieties showed no significant differences. This confirms that cowpea can be used to suppress the growth of nematodes [11]. The *meloidogyne incognita* species were suppressed by the cultivation of cowpea [19]. Nematode ratings and cracking of carrot roots did not show any significant differences among the five N/ha fertilizer levels in both experiments. This confirms that cowpea can be used to suppress the growth of nematodes [19]. Rotating carrot with cereals alongside the application of organic manure will help minimize the impact of nematodes [6]. The amendment also helped to reduce the incidence of nematodes. Organic amendments procedures can also be practiced to control nematodes [6]. Certain lines of cowpea can also suppress the populations of the nematode *Scutellonema cavenessi* [20].

Root length, diameter and harvest index

Carrots grown on Asetenapa amended plots produced significantly the longest carrot roots followed by carrots grown on maize Obatanpa plots which produced the medium carrots root length and Asetenapa amended plots gave the shortest roots in the 2020 carrot season (**Table 3**). This performance could probably be

Table 3. Carrot root length, diameter and harvest index as influenced by preceding crops and N fertilizer level in 2020 and 2021.

Treatment	Root length		Root diameter		Harvest index	
	2020	2021	2020	2021	2020	2021
Variety						
Soronko	13.2	14.5	2.9	3.1	0.6	0.6
Asetenapa	13.5	16.1	2.8	2.8	0.7	0.6
Obatanpa	13.3	14.4	3.1	3.0	0.7	0.5
Mean	13.3	16.0	2.9	3.0	0.7	0.6
LSD (0.05)	0.04	1.4	0.03	1.4	0.05	0.2
Fertilizer (kg N/ha)						
0	13.4	16.2	2.9	2.7	0.7	0.6
30	13.5	15.9	3.0	3.0	0.7	0.6
45	12.7	15.7	2.8	13.0	0.6	0.6
60	13.6	15.8	3.0	3.0	0.7	0.6
90	13.5	16.8	2.9	3.1	0.06	0.6
Mean	13.3	16.0	2.9	3.0	0.7	0.6
LSD (0.05)	1.2	1.5	0.3	0.4	0.09	0.06

attributed to the different levels of N fixation by the two cowpea varieties. Asetenapa cowpea variety and the 90 kg N/ha fertilizer produced the longest roots as 16.1 cm and 16.8 cm respectively. This result conforms to the findings of [21] that carrot is an annual or biennial herb with an erect and branched stems with a fleshy taproot of about 5 - 30 cm long. In the 2020 carrot season, carrots grown after Obatanpa maize variety had roots with the widest diameter, Soronko cowpea variety had carrots with medium diameter, and Asetenapa amended plots had the least carrot root diameter. The five N/ha fertilizer levels were significantly different, with Soronko and Obatanpa producing the best carrot diameter with 3.1 cm. This conforms to the findings of [7], that Organic matter and good soil conditions help carrots produce roots of normal shape and diameter. In the 2021 carrot season however, carrot root diameter did not differ significantly over the sampling periods. The crop varieties produced similar results. This performance could have been boosted by favourable environmental conditions. The use of residues from legumes improves the organic matter content and other physical properties of soil. Soil properties such as structure, bulk density, porosity for root penetration, air circulation, accommodation of microorganisms and increased fertility levels are achieved with the application of adequate quantities of organic manures [22]. Harvest index did not show any significant differences throughout the carrot cultivation. Harvest index is the accumulative effect of dry matter accumulation and partitioning assimilates in the life of a plant. The lack of significant differences recorded by the two carrot seasons may be attributed to equal genetic potential of carrot variety. [23] in a study on marketability of vegetables reported that a marketable length of carrot is about 6 to 9 cm. The longest root produced was 16.78 cm. This showed that root length of carrots produced were longer than the average roots reported by [23]. In the 2021 carrot season, carrots grown on Asetenapa cowpea variety amended plots produced the longest roots, Soronko amended plots produced the carrots with medium roots, while Obatanpa maize variety produced the shortest carrots roots. Asetenapa cowpea generally produced the longest roots probably because it accumulated more dry matter which translated into root development. At harvest in 2020, carrots grown after Obatanpa maize variety had roots with the widest diameter, Soronko maize variety produced carrots with medium diameter, while Asetenapa amended plots gave carrots with the least root diameter. However, they were significantly different among the five N/ha fertilizer levels. More fertilizer increased root length. In a study on the influence of soil amendment on carrot in Asante Mampong, reported that carrot yield and yield components increased due to the amendments in both seasons. The increased carrot yield and other yield components such as root length, root girth and root weight in treated plots, apparently resulted from improved soil chemical and physical properties that were induced by manure application [24].

Carrot root yield and N-credits

Generally, the soil amendment using cowpea varieties led to higher yield (27.9 t/ha) than the 10 - 15 t/ha of carrot reported in Ghana by [18] but was well below

Table 4. Carrot yields as influenced by preceding crops and N fertilizer level in 2020 and 2021.

Treatments	2020			2021		
	Soronko	Asetenapa	Obatanpa	Soronko	Asetenapa	Obatanpa
0	21.6	23.4	19.7	21.8	20.4	18.1
30	21.9	24.4	22.9	25.0	21.3	23.2
45	25.8	27.0	24.3	24.3	20.6	20.9
60	21.9	22.o	27.9	27.0	19.2	22.9
90 kg N/ha	22.0	22.4	26.9	27.4	23.4	20.9
LSD (0.05)		6.60			6.80	

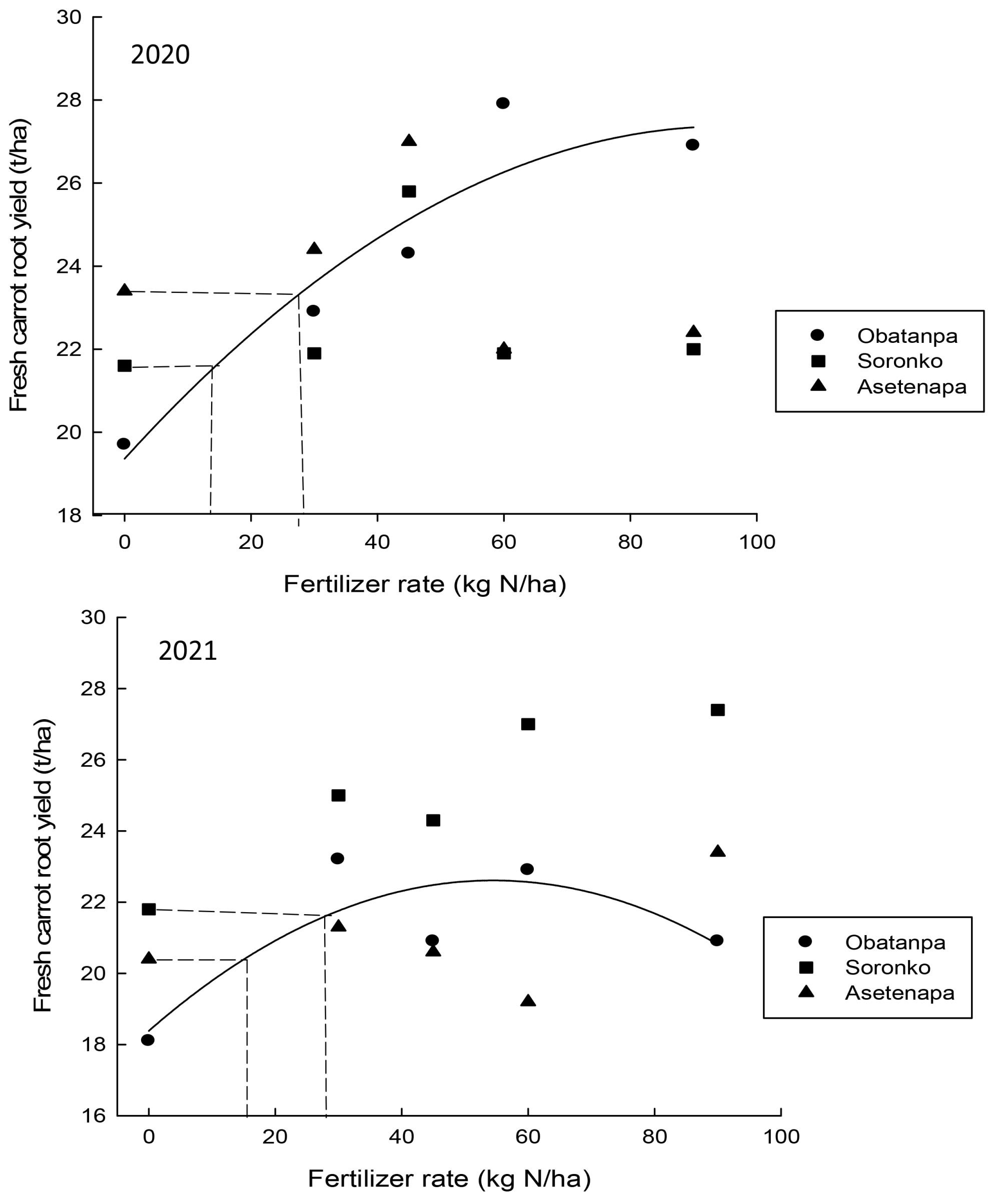

Figure 1. N-credits from Soronko and Asetenapa cowpea varieties to carrot in 2020 and 2021.

the world's average carrot root yield of about 50 - 54 t/ha (USAD, 2005). Carrot yield showed significant differences with carrots planted at 60 kg N/ha applied after Obatanpa maize variety producing the highest root yield (27.9 t/ha). This performance could be due to the existing nutrients in soil. Soil physical composition is of special significance for carrot and yield of most plants, which are normally influenced by different soil and climatic conditions [25]. It was closely followed by Asetenapa cowpea variety with 60 kg N/ha fertilizer level with 27.0 t/ha and Soronko cowpea variety with 30 kg N/ha fertilizer level producing the lowest carrot root yield of 18.1 t/ha in the two carrot seasons. This performance could generally be attributed to improved soil fertility by the amendment and climatic conditions over the period of the 2020 and 2021 carrot seasons. In a soil amendment for carrot studies in Asante Mampong, [24] observed that increased carrot yield and other yield components such as root length, root diameter and root weight in treated plots, and improved soil chemical and physical properties were influenced by the application of organic matter. [22], in a soil amendment study, reported that the application of *Mucuna pruriens* green manure, chicken manure, and their combinations as well as the combination of *Mucuna pruriens* and NPK fertilizer significantly improved soil physical conditions, particularly total porosity and gravimetric moisture content and reduced bulk density.

The cowpea crop varieties used to amend the soil could have generally improved the soil conditions coupled with the relatively stable climatic conditions. The application of organic and inorganic fertilizers supplies plant nutrients for crop growth, plant height and leaves and affect plant physiological processes which serve as important instruments in crop yield [25]. The magnitude of N-credits, determined by the N fertilizer replacement value or index (the amount of N needed in the continuous carrot yield to achieve yield equal to that in rotation with no added N), were greater in both 2020 and 2021 carrot seasons (**Figure 1**). Grain yield of carrot at zero N following Soronko and Asetenapa was large, in both years, resulting in the large N-credits for the succeeding carrot. Asetenapa, an early-maturing cowpea variety, had the largest N-credit (32 kg N/ha), with Soronko, a medium -maturing cowpea variety, giving the lowest N-credit (18 kg N/ha) in 2020. In the 2021 carrot season however, the medium-maturing cowpea variety (Soronko) had the highest N-credit (29 kg N/ha), while the early-maturing cowpea variety (Asetenapa) gave the lowest N-credit (18 kg N/ha). The findings conform to that of Ennin and Dapaah (2008), who reported in a legume-maize rotation study, that greater residual benefits were achieved in Ejura and Pukuase with Mucuna pruriens and Soronko with N-credit values of 14 kg N/ha and 13 kg N/ha respectively. Again, [26] reported more than 90 kg N/ha to maize from mucuna pruriens and medium-cowpea variety "Soronko" with smaller contributions of 22 and 16 kg N/ha from early-maturing cowpea variety "Asontem" and natural fallow respectively. Similarly, [27] studying 13 legume crops including *Mucuna pruriens* reported similar values of N-credits (11 to 96 kg N/ha) in the derived Savanna of West Africa. The N-credits obtained between Soronko and Asetenapa in this research shows that some leguminous crop residues release more N-credits in its first years of incorporation, while others release more in the second years (**Figure 1**). [28] in a maize-legume study observed that there was a trend for Mucuna pruriens as a preceding legume to result in greater yield of maize 2 years later. There were no significant interactions on following carrot yield in the 2020 and 2021 carrot seasons. N application up to 90 kg/ha resulted in a linear response in 2020 carrot season, Obatanpa maize variety, $Y = 19.36 + 0.1677x - 0.000878X^2$ ($r^2 = 0.90$). Similarly, the 2021 carrot seasons had a linear response, Obatanpa maize variety, $Y = 18.384 + 0.1551X - 0.00142X^2$ ($r^2 = 0.72$). Between the two cowpea varieties, carrots following Asetenapa had the largest carrot root yield, followed by carrots grown after Soronko in 2020. In the 2021 however, Soronko gave the largest carrot root yield, followed by Asetenapa. In both seasons, carrots that followed the maize Obatanpa variety had the least yield. The use of leguminous crop residues to amend soil has been reported to have the potential of sustaining soil organic matter and increase in yields of succeeding crops [9] (**Figure 1**).

4. Conclusion

The N-credits obtained between Soronko and Asetenapa in this research shows that N application up to 90 kg/ha resulted in a linear yield response. Carrots that followed the maize Obatanpa variety had the least yield. Generally, the 60 kg N/ha fertilizer level gave significant performance in plant height, number of leaves per plant, dry matter accumulation, low nematodes ratings, and carrot root length. Asetenapa and Soronko cowpea varieties contributed positively in amending the soil for the carrot cultivation as they combined with 60 kg N/ha for highest carrot yield of 27.9 t/ha which was significantly higher than the average yield for Africa (12 - 20 t/ha). The amended plots recorded increased yields compared with the control plots. Obatanpa maize variety with 0 kg N/ha fertilizer level produced the lowest carrot yield, indicating that the soil amendment increased yields. Carrot root forking and cracking were suppressed by the cowpea amendment as the amended plots recorded minimal cracked and forked carrot roots.

5. Recommendation

Since organic manure releases both major and minor nutrients, carrot and vegetable farmers are advised to use any available manure including cowpea residuals for effective growth and yield since cowpea is grown in every part of the country. Resource-poor farmers can also benefit from the cowpea grain as well as higher carrots yields to increase their household incomes. Further research should be carried out on the use of cowpea residues to amend soil for the cultivation of other vegetables such as tomato, pepper, lettuce, cabbage, etc. In addition, studies comparing cowpea with other legumes such as soybean, groundnuts and *Mucuna pruriens* to estimate their N-credits to carrots could be carried out. This further research could eventually lead to organic vegetable cultivation for both domestic consumption and foreign export.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Statista (2019) Global Production Volume of Vegetables from 2000 to 2017. https://www.statista.com/

[2] Muendo, K.M. and Tschirley, D. (2004) Improving Kenya's Domestic Horticultural Production and Marketing System: Current Competitiveness, Forces of Change, and Challenges for the Future (Volume III: Horticultural Research and Seed Sector R.). Michigan State University, Department of Agricultural, Food, and Resource Economics, Food Security Collaborative Working Papers.

[3] Berinyuy, J.E. and Fontem, D.A. (2011) Evaluating Post-Harvest Opportunities and Constraints to Utilization and Marketing of African Leafy Vegetables in Cameroon. *African Journal of Food*, *Agriculture*, *Nutrition and Development*, **11**, 4647-4663. https://doi.org/10.4314/ajfand.v11i2.65919

[4] Ahmad, Z., Ali, N., Ahmad, M., Ulhag, S. and Ahmad, S. (2005) Yield and Economics of Carrot Production in Organic Farming. *Sarhad Journal of Agriculture*, **21**, 357-364.

[5] Ministry of Food and Agriculture (2017) Agricultural Sector Progress Report, 2016. Monitoring and Evaluation Directorate, Accra. http://www.mofa.gov.gh

[6] Appiah, S.F., Sarkodie-Addo, J. and Opoku, A. (2017) Growth and Yield Response of Carrot (*Daucus carota* L.) to Different Green Manures and Plant Spacing. *Journal of Biology*, *Agriculture and Healthcare*, **7**, 16-23.

[7] Ndungu, S.M., *et al.* (2018) Cowpea (*Vigna unguiculata* L. Walp) Hosts Several Widespread Bradyrhizobial Root Nodule Symbionts across Contrasting Agro-Ecological Production Areas in Kenya. *Agriculture*, *Ecosystems and Environment*, **261**, 161-171. https://doi.org/10.1016/j.agee.2017.12.014

[8] Shah, A., Nazari, M., Antar, M., Msimbira, L.A., Naamala, J., Lyu, D., *et al.* (2021) PGPR in Agriculture: A Sustainable Approach to Increasing Climate Change Resilience. *Frontiers in Sustainable Food Systems*, **5**, Article 667546. https://doi.org/10.3389/fsufs.2021.667546

[9] Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. (2017) Multiple Benefits of Legumes for Agriculture Sustainability: An Overview. *Chemical and Biological Technologies in Agriculture*, **4**, Article No. 2. https://doi.org/10.1186/s40538-016-0085-1

[10] Kebede, E. (2020) Grain Legumes Production in Ethiopia: A Review of Adoption, Opportunities, Constraints and Emphases for Future Interventions. *Turkish Journal of Agriculture—Food Science and Technology*, **8**, 977-989. https://doi.org/10.24925/turjaf.v8i4.977-989.3254

[11] Kebede, E. (2020) Grain Legumes Production and Productivity in Ethiopian Smallholder Agricultural System, Contribution to Livelihoods and the Way Forward. *Cogent Food & Agriculture*, **6**, Article 1722353. https://doi.org/10.1080/23311932.2020.1722353

[12] Meena, B.P., Fagodiya, R.K., Prajapat, K., Dotaniya, M., Kaledhonkar, M., Sharma, P., *et al.* (2018) Legume Green Manuring: An Option for Soil Sustainability. In: Meena, R., Das, A., Yadav, G. and Lal, R., Eds., *Legumes for Soil Health and Sus-*

tainable Management, Springer Singapore, Singapore, 387-408. https://doi.org/10.1007/978-981-13-0253-4_12

[13] Nanganoa, L.T., Njukeng, J.N., Ngosong, C., Atache, S.K.E., Yinda, G.S., Ebonlo, J.N., *et al.* (2019) Short-Term Benefits of Grain Legume Fallow Systems on Soil Fertility and Farmers Livelihood in the Humid Forest Zone of Cameroon. *International Journal of Sustainable Agricultural Research*, **6**, 213-223. https://doi.org/10.18488/journal.70.2019.64.213.223

[14] Lengwati, D.M., Mathews, C. and Dakora, F.D. (2020) Rotation Benefits from N_2-Fixing Grain Legumes to Cereals: From Increases in Seed Yield and Quality to Greater Household Cash-Income by a Following Maize Crop. *Frontiers in Sustainable Food Systems*, **4**, Article 94. https://doi.org/10.3389/fsufs.2020.00094

[15] Soil Research Institute (1999) Soil Map of Ghana, FAO/UNESCO (1990). Land Suitability Section, Soil Research Institute, CSIR, Ghana.

[16] SAS (1999) Statistical Analysis System, Statistical Methods. SAS Institute Inc., Cary.

[17] Bundy, L.G., Dndraski, T.W. and Wolkoski, R.P. (1993) Nitrogen Credit in a Soya Bean-Corn Crop Sequences on Three Soils. *Agronomy journal*, **85**, 138-143. https://doi.org/10.2134/agronj1993.00021962008500050020x

[18] Dawuda, M.M., Boateng, P.Y., Hemeng, O.B. and Nyarko, G. (2011) Growth and Yield Response of Carrot (*Daucus carota* L.) to Different Rates of Soil Amendments and Spacing. *Journal of Science and Technology*, **31**, 11-20. https://doi.org/10.4314/just.v31i2.69389

[19] Wang, K.H., Mcsorley, C. and Gallaher, R.N. (2003) Host Status and Amendment Effect of Cowpea on *Meloidogyne incognita* in Vegetable Production Systems. *Nematropica*, **33**, 214-223.

[20] Anthony, E.H. (2012) Phenotyping Cowpeas for Adaptation to Drought. *Frontiers in physiology*, **3**, Article 155. https://doi.org/10.3389/fphys.2012.00155

[21] Rai, N. and Yadav, D.S. (2005) Advances in Vegetable Production. Researchco Book Centre, New Delhi.

[22] Atta Poku, P. (2012) Influence of *Mucuna pruriens* Green Manure, NPK and Chicken Manure Amendments on Soil Physico—Chemical Properties, Growth and Yield of Carrot (*Daucus carrota* L.*)* M. Phil Thesis, Department of Crop and Soil Science Education, Faculty of Agriculture Education, University of Education, Winneba.

[23] Adarkwa, I. (2012) Assessment of the Postharvest Handling of Six Major Vegetables in Two Selected Districts in Ashanti Region of Ghana. Ph.D. Thesis, Kwame Nkrumah University of Science and Technology, Kumasi.

[24] Atakora, K. (2011) Influence of Grasscutter, Poultry Manure and NPK Amendments on Soil Characteristics, Growth and Yield Response of Carrot (*Daucus carota*). M.Phil Thesis, Department of Crop and Soil Science Education, Faculty of Agriculture Education, University of Education, Winneba.

[25] Subedi, S., Srivastava, A., Sharma, M.D. and Shah, S.C. (2018) Effect of Organic and Inorganic Nutrient Sources on Growth, Yield and Quality of Radish (*Raphanus sativus* L.) Varieties in Chitwan, Nepal. *SAARC Journal of Agriculture*, **16**, 61-69. https://doi.org/10.3329/sja.v16i1.37423

[26] Ennin, S.A., Dapaah, H.K. and Abaidodoo, R.C. (2004) Nitrogen Credits from Cowpea, Soybean to Maize in Rotation. *West African Journal of Applied Ecology*, **6**, 65-74.

[27] Tian, G., Kolawole, G.O., Kang, B.T. and Kirchhof, G. (2000) Nitrogen Fertilizer

Replacement Indexes of Legume Cover Crops in the Derived Savanna of West Africa. *Plant and Soil*, **224**, 287-296. https://doi.org/10.1023/A:1004873206350

[28] Ennin, S.A. and Dapaah, H.K. (2008) Legumes in Sustainable Maize and Cassava Cropping Systems in Ghana, Kumasi, Ghana. *Agricultural and Food Science Journal of Ghana*, **7**, 519-521. https://doi.org/10.4314/afsjg.v7i1.43032