American Journal of Plant Sciences, 2022, 13, 702-721
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Effects of Green Manure and Inorganic Fertilizers on the Growth, Yield and Yield Components of Soybean (*Glycine max* (L.) Merr.) in the Mount Cameroon Region

Enow Andrew Egbe[1,2*], Nkeutcha Marietta Solange Soupi[1], Miranda Egbe Awo[1], George Ayamba Besong[1]

[1]Department of Plant Science, Faculty of Science, University of Buea, Buea, Cameroon
[2]Faculty of Agriculture and Veterinary Medicine, University of Buea, Buea, Cameroon
Email: *egbe1@yahoo.com

How to cite this paper: Egbe, E.A., Soupi, N.M.S., Awo, M.E. and Besong, G.A. (2022) Effects of Green Manure and Inorganic Fertilizers on the Growth, Yield and Yield Components of Soybean (*Glycine max* (L.) Merr.) in the Mount Cameroon Region. *American Journal of Plant Sciences*, **13**, 702-721.
https://doi.org/10.4236/ajps.2022.135047

Received: April 5, 2022
Accepted: May 28, 2022
Published: May 31, 2022

Abstract

This study evaluates the effects of green manure, inorganic fertilizers and their combinations on the growth and yield of soybeans in the Mount Cameroon Region. The experiment involved 10 treatments which include, 5 Mg/ha green manure, 180 Kg P/ha triple superphosphate fertilizer (P), 180 Kg/ha NPK (20:10:10), 2 Mg/ha green manure + 90 kg P/ha, 3 Mg/ha green manure + 90 kg P/ha, 5 Mg/ha green manure + 90 Kg P, 2 Mg/ha green manure + 90 kg NPK/ha, 3 Mg/ha green manure + 90 kg NPK/ha, 5 Mg/ha green manure + 90 kg NPK and a control. Plant growth characters were assessed every 14 days for a period of 70 days for the late (August) and early (March) planting seasons. The results indicated that plants supplied with 5 Mg/ha green manure had the highest plant heights of 60.7 cm, and this was significantly different from the control which had the least height (52.76 cm). Stem collar diameter was significantly ($p < 0.001$) increased with treatments in both seasons. Plants supplied with 5 Mg/ha green manure recorded the highest stover yield (10.59 Mg/ha), and this was significantly different from the control which had the least (6.64 Mg/ha). Plants supplied with 5 Mg/ha green manure had the highest days to flowering (38 days), while plants supplied with 5 Mg/ha green manure + 90 Kg NPK had the least (33 days) which was significantly different ($p < 0.01$). The highest number of pods per plant was observed in plants supplied with 5 Mg/ha green manure (57 pods per plants), which was significantly different from the control (39 pods per plant). Plants supplied with 5 Mg/ha green manure + 90 Kg NPK recorded the highest grain yield (4.97 Mg ha^{-1}), while the lowest grain yield was observed in the control (2.22 Mg ha^{-1}). Results from this study can be used by soybeans farmers in the Mount Cameroon region to enhance productivity of this crop and thereby improving their living standards and food security in Cameroon.

Keywords

Green Manure, Inorganic Fertilizer, Flowering Period, Pod Formation, Yield, Soybeans

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is a pulse, that is grown in the tropical, subtropical, and temperate climates. In global annual production of legumes, soybean was ranked one of the most important grain legumes in the world due to its edible cholesterol free oil, cheapest source of protein and fixation of atmospheric nitrogen and as fodder for livestock [1]. An increase in world's population is causing pressure on land leading to the replacement of traditional shifting cultivation. The adoption of inappropriate farming methods has resulted to land degradation and clearance of new forest land for agriculture. Application of plant residues is a well-known agricultural practice for maintaining soil nutrient levels and ameliorating soil physical properties to sustain crop production [2]. Cheng *et al.* [3] indicated that plant residues from planted fallow or pruning from hedgerows in alley cropping systems can contribute significant quantities of nutrients to the associated crops. Rajasekar *et al.* [4] found that crop plants growing in the agroforestry plots had significantly higher growth and yield than those in purely arable crop plots. Farmers in the mid-altitudes of mount Cameroon region carry out farming on originally rich volcanic soils that are now degraded because of high pressure on land, erosion and lack of good soil management practices to maintain its fertility. The nutrient content of organic fertilizers varies widely depending on the source and moisture content and there is also the problem of slow and variable release rates of nutrients during decomposition of organic materials [5].

In the past, the practice of green manuring (GM) was being ignored due to easy availability and low cost of inorganic fertilizers but in recent years the price of inorganic fertilizers has doubled. This has a major consequence on food production as most resource poor farmers do not have the finances to purchase inorganic fertilizers. Through decomposition, green manure can supply 55 - 175 kg N ha^{-1} [6]. However, recently the interest in using green manure has emerged among researchers and farmers with the advent of high yielding cultivars and escalating fertilizer prices. Incorporating leguminous crops into the soil even in alternate years considerably increases soil N [7] and reduces the need for N fertilizers [8]. Green manuring also maintains soil P, enhances organic matter content and improves the soil's physical condition and chemical properties [9]. Incorporation of green biomass into the soil influences nutrients in different ways. Besides facilitating the dissolution of inorganic phosphorus [10] and increasing biochemical availability of nutrients to plants [11], they also increase crop yield by improving infiltration rates [12].

Though organic fertilizers supply large quantities of nitrogen required by crops to obtain maximum yields, there is the need to supplement organic fertilizers with inorganic fertilizers for a more sustainable and productive system [13]. Organic and chemical fertilizers have shown significant complimentary effects on the growth and yield of arable crops [14] [15]. Organic fertilizers can be made of various heterogenous substances which can be divided into physical and chemicals fractions. The incorporation of green manure has shown to stimulate increase of microbial biomass and enzyme activities which associated with nutrient transformation and thereby increasing soil internal cycling of nutrients [16] [17]. The use leguminous green manure improves soil organic carbon, pH, nitrogen and phosphorus circulation activities which increases crop yield and sustainable crop productivity when compared with sole chemical fertilizers [18] [19] [20]. Studies have shown that with use of organic fertilizers, soil microbial biomass and diversity increases as compared when chemical fertilizers are used alone [18].

Although the effect of green manures and fertilizers on the growth and yield of soybeans in the Mount Cameroon region has been studied separately, there is very little information on the quantity of organic manure and inorganic fertilizer or their combination on the growth, yield and yield components of this crop. It is hypothesized that, the improvement of the physical properties of soil due to green manure application shall influence crop growth characteristics which ultimately influences the productivity and input use efficiency of soybean. This study therefore investigates the optimum quantities of green manure, inorganic fertilizers and their combinations on the growth, yield and yield components of soybeans in the Mount Cameroon region.

2. Materials and Method

2.1. Materials and Experimental Design

The study was carried out for two seasons, 2018 late rains in August and 2019 early rains, (March) in the University of Buea Plant Science demonstration farm. It is located between latitude 3˚57'N to 4˚27'N and longitude 8˚58'E to 9˚25'E (**Figure 1**). It is situated on the eastern slope of Mount Cameroon and has a humid tropical climate with a mean annual rainfall of 2800 mm per annum, most of which is received between June and September [21]. The mean annual temperature is 27˚C while the average relative humidity is 80% - 86% and the annual sunshine is 900 to 1200 hours per annum [22]. The area is mountainous with thick and evergreen forest vegetation at the lower slope of the mountain and there are transitional changes in vegetation type along altitudinal gradients. The soil type at the upper slope is mainly volcanic, rich in mineral content and suitable for agriculture. The lower slopes of the mountain have ancient ferralitic soils of highly weathered substrates which are deeper and low in plant nutrients [21].

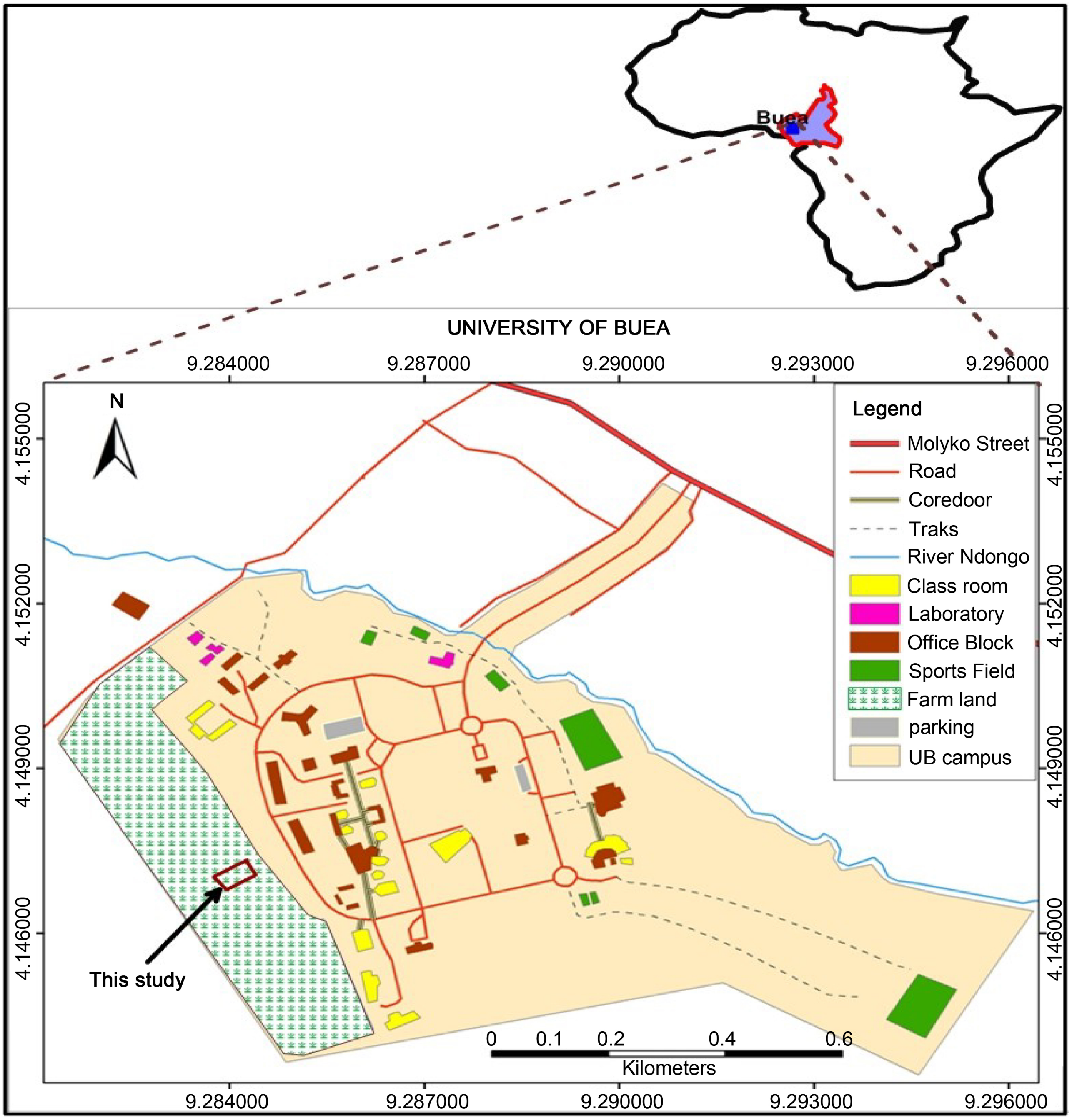

Figure 1. Location of the study site.

The experimental field (04˚08'48.9"N, 00917'03.3"E, altitude of 450 m above sea level) was located in the demonstration farm of the Department of Plant Science. Agriculture is the major activity in this region and this is done mostly by shifting cultivation and organized commercial plantations by CDC (Cameroon Development Corporation) [22]. This area is characterized by rapid population growth, high agricultural productivity, and increasing demands for agricultural resources. The farming systems are complex, consisting of an integration of crops, trees, livestock, and smallholder farms that are intensively managed. The main cash crops are rubber, oil palm, cocoa and tea while the main staple food crops are maize (*Zea mays* L.), cassava (*Manihot esculenta*), cocoyam (*Collocasia* spp) mostly intercropped with other crops. Other food crops include sweet potatoes (*Ipomoea batatas* (L.) Lam), bananas (*Musa spp.* L.) and vegetables that are mainly grown for subsistence. Figure 2 shows the mean monthly rainfall and temperature of Buea during the study period.

2.2. Soil Sampling and Analysis

Soil samples were collected at the experimental site before ploughing. They were collected randomly with a soil auger at a depth of 0 - 20 cm plough layer. The soils were bulked and mixed to have a homogenous sample and this was air-dried, and later sieved with a 2 mm sieve. The sieved samples were coded and sent to IITA (International Institute of Tropical Agriculture) Laboratory for routine chemical analyses.

2.3. Plant Sample Collection and Analyses

Green manure (*Pueraria phaseoloides*) was collected from fallow lands within the University of Buea (Campus A). One kg of fresh green manure was weighed in triplicates with a balance and this was cut into smaller parts and put into large envelopes. These samples were oven dried at 105˚C to constant weight to have the dry weight of the green manure. Another sample of the green manure was oven dried at 70˚C for 48 hours, ground and the sample sieved with a 0.5 mm sieve. The sieved sample was coded and sent to IITA Laboratory for routine chemical analyses.

2.4. Experimental Design and Treatments

The experiment had ten treatments and was carried out during the late planting season (August 2018 and early planting season (March 2019). The treatments

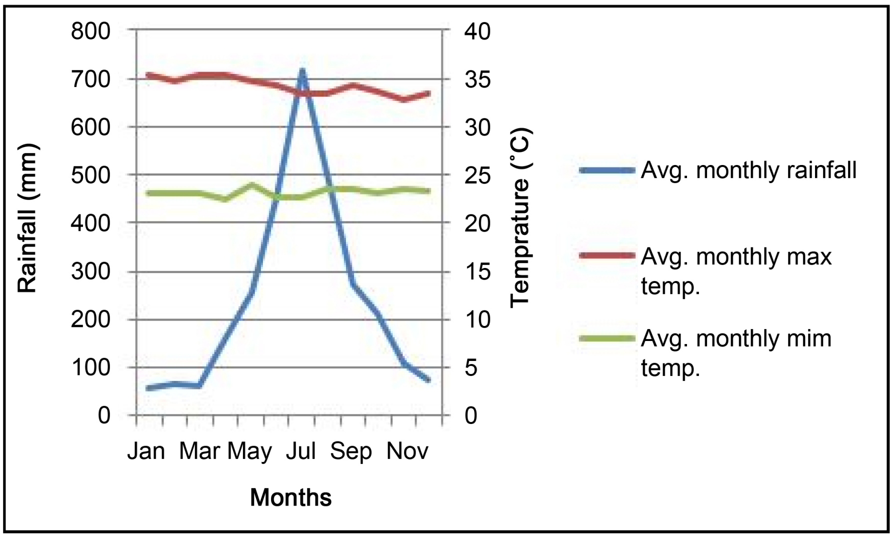

Figure 2. Mean monthly rainfall and temperature during 2018 and 2019 cropping seasons.

comprised of green manure, Triple Superphosphate (TSP) and N P K in single or various combinations as shown in Table 1.

The total surface area of the research plot was 2240 m^2 that is 70 m by 32 m. The experiment was a randomized complete block design (RCBD) with three replicates. Each plot was 8 × 4.0 m (32.0 m^2) and a distance of 2 and 4 m was created to separate the various treatments and blocks respectively. The same plots were maintained for the two planting periods.

Prior to planting in each season, the land was ploughed to a depth of 15 cm using a hand hoe. Green manure was uniformly distributed on the treatment plots and then incorporated within 15 cm soil depth, one week before planting. The soybean variety $TGX1910^{-1}$ 4F was planted at the rate of 3 seeds per hole, planting depth of about 3 - 4 cm and 50 × 20 cm spacing. Two weeks after emergence, the seedlings were thinned to two (2) plants per stand to adjust plant density to 200,000 plants per hectare. Weeding was done three times each season using a hand hoe. Insecticide was sprayed against insects twice during late planting season and three times during early planting season due high incidence of insect pest during this period.

2.5. Assessment of Morphological Characteristics

To evaluate the effect of treatments on soybean development, fifteen plants were tagged for each treatment and for each replicate. Plant height was measured every two weeks for 70 days. It was measured with a meter rule from the ground level to the tip of the plant and the mean height calculated. The collar diameter of the stem was measured using a Vernier calliper (Mitutoyo, Japan) at the collar of the plant. The number of leaves was assessed from the 15 tagged plants per plot per treatment by counting the number of leaves for the 15 plants and the mean number calculated.

Table 1. Experimental treatment descriptions and their abbreviations.

TREATMENT DESCRIPTIONS	ABBREVIATIONS
5 Mg of green manure per hectare	5TGM
180 kg of P_2O_5 per hectare	P
180 kg of N P K per hectare	NPK
2 Mg of green manure + 90 kg of P_2O_5 per hectare	2TGM + P
3 Mg of green manure + 90 kg of P_2O_5 per hectare	3TGM + P
5 Mg of green manure + 90 kg of P_2O_5 per hectare	5TGM + P
2 Mg of green manure + 90 kg of N P K per hectare	2TGM + NPK
3 Mg of green manure + 90 kg of N P K per hectare	3TGM + NPK
5 Mg of green manure + 90 kg of N P K per hectare	5TGM + NPK
Control application	CL

The relative leaf area was measured using a measuring tape at two weeks intervals for 70 days. This was done for six leaves per plant (eighteen leaflets) selected from the fifteen tagged plants for each plot. The mean relative leaf area was then multiplied by the total number of leaves per plant to represent the relative leaf area per plant in the treatment. For the actual leaf area; six leaves were randomly selected from tagged plants, harvested and taken to the Life Sciences Laboratory and leaf area per plant was recorded to the nearest 0.01 cm^2 with the use of a leaf area meter (Delta T MK2, Cambridge-England). In order to estimate the stover yield, the same tagged plants in each plot were harvested separated into pods and stover. The average fresh weight of green plants was recorded. This was oven dried at 70˚C to constant weight and the dry weight recorded with an electronic balance. To assess the below ground biomass characters, the plots were irrigated for two days during the late planting season to soften the soil. Some plants were carefully uprooted after pod harvest. The number of primary lateral roots was counted and the length of the main taproot was measured using a metre rule. Root volume was also determined as described by [21].

The root nodule number and nodule weight were assessed by randomly selecting five plants in each plot. These plants were carefully dug out seven weeks after germination. This is because at this stage of development, most of the food reserves are used for vegetative growth. A spade was used to dig a circle of 15 cm radius around the plant at a depth of 30 cm. The plant was lifted slowly from the soil clump and placed carefully in a plastic bag and transported to the Life Sciences Laboratory of the University of Buea. In the laboratory, the plant shoots were cut and roots washed under running water with a sieve underneath to collect any detached nodules. The root nodules were cut from the roots, counted and recorded. The fresh weight of the nodules was recorded with an electronic balance.

2.6. Assessment of Reproductive and Yield Characteristics

The following parameters were assessed during the study:

1) Days to 50% flowering, which refers to the number of days from sowing to the time when 50% of the plants have at least one open flower.

2) Days to 50% podding referring to the number of days from sowing to the time when 50% of plants have at least one pod. The numbers of pods per plant for fifteen tagged plants from each plot were counted and mean calculated to represent the number of pods per plant in that treatment.

3) Grain yield: At pod maturity, the fifteen tagged plants from each of the treatment in each replicate were used to assess the number of pods per plant, seeds per pod, and 1000 seed weight. Grain yield per hectare was calculated from the grain yield per area harvested. Pods were separated from the plants and sun dried. All these pods were shelled, and the grains winnowed to remove any plant debris and weighed with a sensitive balance to determine the mean grain yield per plant. The mean number of seeds per pod was calculated by using the fol-

lowing formula [23].

$$\text{Number of grains per pod} = \frac{\text{number of grains/plant}}{\text{amount of pods/plant}} \quad (1)$$

2.7. One Thousand (1000)—Seed Weight

One thousand (1000) seed weight and yield were taken randomly from the tagged plants of each treatment, and weighed on a sensitive balance. Thereafter, the yield (Mg ha^{-1}) was calculated at 12% moisture content (standard) using the following formulae in Equations (2), (3), and (4) as described by [23].

$$\text{DM}(\text{kg}) = \frac{\text{Sample fresh Weight}(\text{g}) - \text{Sample Dry Weight}(\text{g})}{1000} \quad (2)$$

$$\text{Yield}\left(\text{ton} \cdot \text{ha}^{-1}\right) = 10 * \frac{\text{DM}(\text{kg})}{\text{Harvested area}\left(\text{m}^2\right)} \quad (3)$$

$$\text{Yield}_{\text{adjusted}}\left(\text{ton} \cdot \text{ha}^{-1}\right) = \text{Measured yield} * \frac{100 - \text{Sample moisture content}}{100 - \text{Standard moisture content}} \quad (4)$$

Harvest Index (HI), which expresses the efficiency of a crop variety to convert the dry matter into economic yield was also determined by the use of the following formula.

$$\text{Harvest Index} = \frac{\text{Grain yield}(\text{kg}) * 100}{\text{Total Dry Matter yields}(\text{kg})} \quad (5)$$

2.8. Statistical Data Analyses

The data were tested for normality and homogeneity and analysed using One Way Analysis of Variance (ANOVA). Statistical analyses were carried out using MINITAB version 17. The means were separated by Tukeys Honest Significant Difference (HSD) test at $p \leq 0.05$. A correlation analysis was conducted to determine the relationship between the measured parameters of soybean (yield, fill pod, shoot dry weight and root dry weight).

3. Results

The nutrient content of green manure and the initial soil chemical properties are presented in **Table 2** and **Table 3** respectively.

3.1. Effects of Treatments on the Morphological Characters of Soybean

Figure 3 shows the influence of treatments on the growth patterns of soybeans with respect to height. There was exponential growth from the 14 to 28 days after planting and thereafter an increase in height until 42 days after planting, From the 42 days after planting, there was no net increase in height in all the treatments.

Effects of various treatments on growth performance of soybeans are presented in **Table 4** and **Table 5**. There were significant differences ($p = 0.05$) in

Table 2. Nutrient content supplied by green manure.

Parameters	Conc. of Green manure	Total dry biomass kg/ha of green manure			Nutrient supplied by green manure(kg/ha)		
		2 Mg*	3 Mg	5 Mg	2 Mg	3 Mg	5 Mg
Organic carbon (%)	40.51	500 Kg	750 Kg	1250 Kg	202.55	303.83	506.38
Total Nitrogen (%)	2.86	500 Kg	750 Kg	1250 Kg	14.3	21.45	35.75
Available P (%)	0.35	500 Kg	750 Kg	1250 Kg	1.75	2.63	4.38
K^+ (%)	2.16	500 Kg	750 Kg	1250 Kg	10.8	16.2	27
Mg^{2+} (%)	0.28	500 Kg	750 Kg	1250 Kg	1.4	2.1	3.5
Ca^{2+} (%)	1.07	500 Kg	750 Kg	1250 Kg	5.35	8.03	13.38
Carbon/nitrogen ratio	14.16	-	-	-	-	-	-

1kg of fresh green manure = 500 g of dry biomass of green manure.

Table 3. Initial soil chemical properties of experimental plot.

Chemical properties	Soil
pH in water	5.24
Organic Carbon (%)	2.35%
Total Nitrogen (%)	0.26%
Available P (mg·kg^{-1} soil)	11.85
K^+ (cmol(+) kg^{-1} soil)	0.11
Mg^{2+} (cmol(+) kg^{-1} soil)	2.48
Ca^{2+} (cmol(+) kg^{-1} soil)	8.89
CEC (cmol(+) kg^{-1} soil)	16.80

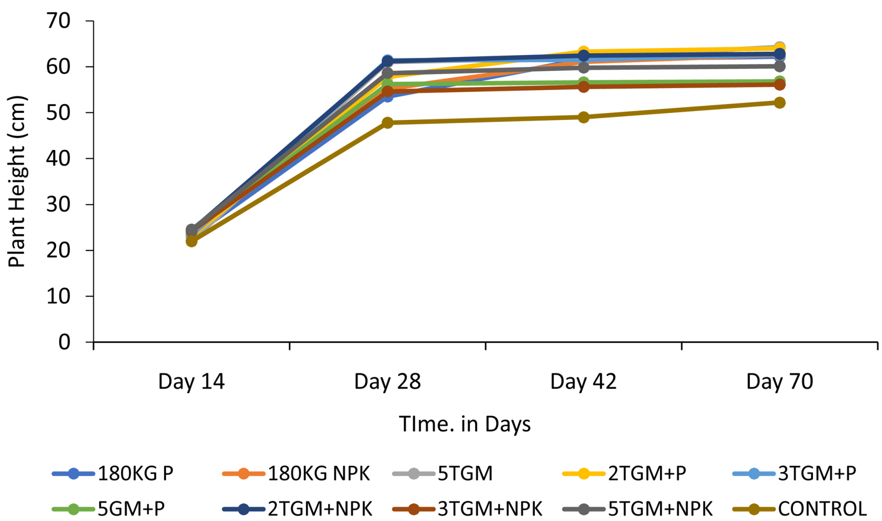

Figure 3. The effects various treatments on allometric growth pattern of soybean with time.

Table 4. Effects of treatments on morphological parameters of soybeans during the late planting season.

Treatments	Plant height (cm)	Collar diameter (mm)	Leaf number	Number of branches	Leaf area (cm^2)	Length of root (cm)	Number of nodules	Nodule weight (g)	Stover yield (Mg/ha)
5TGM	60.20	24.8	33.2	8.3	121	35.06	15	1.9	7.74
P. fertilizer	59.26	22.09	29.2	7.3	84.5	28	10.67	2.2	5.54
NPK	59.53	22.49	31.6	8	96.4	31.3	26.67	2.8	6.63
2TGM + P	53.40	16.07	32.7	8	112.7	24	33.6	3.3	6.68
3TGM + P	59.20	15.35	33.5	8.1	97.6	26.02	22.3	2.1	6.27
5TGM + P	53.23	13.17	30.4	7.6	98.2	25.6	16.3	1.7	5.97
2TGM + NPK	57.56	23.2	31.2	7.6	104	26.9	11.6	2	5.29
3TGM + NPK	55.26	16.63	30.9	7.6	118.3	27.8	23.3	2.5	5.83
5TGM + NPK	56.30	26.2	30.1	7.6	104.3	26	21.6	2.6	6.18
Control	52.26	15.2	28	6	72.6	27	23	2.1	3.62
Mean	56.62	19.52	31.08	7.61	100.96	27.768	20.404	2.32	5.975
Coeff. Var	5.22	24.03	5.65	8.44	14.67	11.52	34.73	20.7	17.99
P-value	NS	0.05	NS	NS	NS	0.004	0.001	NS	0.002

Table 5. Effects of treatments on the morphological parameters of soybeans during the early planting season.

Treatments	Plant height (cm)	Collar diameter (mm)	Leaf number	Number of branches	Leaf area (cm^2)	Length of root (cm)	Number of nodules	Nodule weight (g)	Stover yield (Mg/ha)
5TGM	60.7	14.1	35.0	10.0	138.05	33.2	25	4.9	11.22
P. fertilizer	59.76	13.1	33.0	9.0	94.9	26	21	4.8	11.90
NPK	60.03	17.3	33.0	8.0	104.0	28	37	6	11.32
2TGM + P	53.9	15.1	34.0	9.0	125.3	29.03	44	6.8	11.06
3TGM + P	59.7	15.3	35..0	8.0	107.6	26.3	35	5.7	11.46
5TGM + P	53.73	15.4	31.0	9.0	108.3	28.3	32	5.3	11.91
2TGM + NPK	58.06	25	31.0	9.0	113.1	25.06	24	5.1	9.84
3TTGM + NPK	55.76	24.5	32.0	10.0	128.9	28	33	5.6	9.86
5TGM + NPK	56.8	25.1	34.0	9.0	114.3	27.08	34	5.7	10.80
Control	52.76	17.6	29.0	9.0	81.1	28.06	31	5.6	9.04
Mean	57.12	18.25	33.0	9.0	111.55	27.90	31.51	5.55	10.84
Coeff. Var	4.91	24.71	5.65	6.11	14.14	7.56	20.24	9.98	8.39
P-value	0.003	0.008	NS	NS	NS	0.012	0.026	NS	0.003

plant heights during the early and late planting seasons. In the late and early planting seasons, the plants supplied with 5 Mg of green manure (5TGM) had the tallest plants (60.2 cm and 60.7 cm respectively) and this was significantly different from the control (52.2 cm and 52.8 cm respectively). There were significant differences in the collar diameter in the two planting periods. In the late and early planting seasons, the highest collar diameter was observed in plants supplied with 5TGM + NPK fertilizer (26.2 mm and 25 mm respectively) while the control had 15.2 mm and 13.1 mm respectively).

There were significant differences ($p = 0.05$) in the length of taproot during the early and late planting seasons. In the late and early planting seasons, plants supplied with 5 Mg of green manure (5TGM) had the longest taproot (35.06 cm and 33.2 cm respectively) and this was significantly different from plants supplied with 2TGM + P fertilizer (24 cm and 24.1 cm respectively) which had the least taproot length.

Results of the number of leaves per plant in soybean at fourteen days intervals showed that there was no significant difference in number of leaves for both seasons (Table 4 and Table 5). During the late and early planting seasons, the highest number of leaves was recorded with plants supplied with 3TGM + P treatment with a value of 34 and 35 respectively and this was not significantly different from the control that recorded the least.

There were no significant differences ($p = 0.74$) in the leaf area during both planting seasons. In the late and early planting seasons, the plants supplied with 5 Mg of green manure (5TGM) had the largest mean leaf area (121 cm^2 and 138 cm^2 respectively) and this was not significantly different from the control (72.6 cm^2 and 81.1 cm^2 respectively). There were no significant differences ($p = 0.05$) in the number of branches per plant during the early and late planting seasons. In the late planting periods, the plants supplied with 5 Mg of green manure (5TGM) had the highest number of branches per plant (8) and this was not significantly different from the control (6.0). During the early planting season, the plants supplied with 5 Mg of green manure (5TGM) also had the highest number of branches per plant (10) when compared with plants supplied with 180 Kg/ha NPK and 3GM + P recorded the lowest number of branches (8). There was a significant difference ($p \leq 0.05$) on the number of root nodules in both seasons. During late and the early planting seasons, plants supplied with 2TGM + P recorded the highest number of root nodules (34), while plants supplied with 180 Kg P/ha recorded the lowest (11 and 21 respectively). There were no significant differences ($p = 0.05$) in the nodule weight per plant during the early and late planting seasons as shown in Table 4 and Table 5.

There were significant differences ($p = 0.05$) in stover yield during the early and late planting seasons. In the late and early planting seasons, the plants supplied with 5 Mg ha^{-1} of green manure (5TGM) had the highest stover yield (9.96 Mg ha^{-1} and 11.91 Mg ha^{-1} respectively) and this was significantly different from the control (4.24 Mg ha^{-1} and 6.64 Mg ha^{-1} respectively).

3.2. The Effects of Treatments on the Reproductive and Yield Characters

Table 6 and Table 7 show the effects of treatments on the reproductive and

Table 6. Effects of treatments on reproductive and yield characteristics of soybeans in late planting season.

Treatments	Days to 50% flowering	Days to 50% podding	No. of pods/plant	1000 seeds weight (g)	Grain yield (Mg/ha)	Harvest index
5TGM	36.0	45.0	54.33	150.9	4.02	0.11
P. fertilizer	39.3	45.3	40.67	150.5	2.62	0.11
NPK	34.8	42.0	43.67	140.4	2.63	0.10
2TGM + P	35.3	42.3	49.33	150.5	2.68	0.11
3TGM + P	41.0	45.0	49.0	160.0	2.27	0.12
5TGM + P	40.0	46.0	50.33	150.7	3.32	0.10
2TGM + NPK	33.0	44.0	48.33	160.5	2.29	0.10
3TGM + NPK	34.5	42.6	51.33	150.7	4.43	0.10
5TGM + NPK	32.7	43.6	42.33	150.9	4.97	0.10
Control	38.6	45.3	37	150.6	2.22	0.11
Coeff. Var	8.16	3.23	11.67	30.42	17.99	6.60
P-value	0.001	0.01	NS	NS	0.001	NS

Table 7. Effects of treatments on reproductive and yield characteristics of soybeans in the early planting season.

Treatments	Days to 50% flowering	Days to 50% podding	No. of pods/plant	1000 seeds weight (g)	Grain yield (Mg/ha)	Harvest index
5TGM	38	43	59	170.6	3.02	0.11
P. fertilizer	37.3	42.9	45	170.8	2.92	0.10
NPK	35.6	39	48.3	160.4	2.83	0.11
2TGM + P	36.0	38	53.6	170.7	2.48	0.12
3TGM + P	36.8	42	53.3	170.7	2.37	0.10
5TGM + P	36.0	43	54.6	170.9	3.62	0.10
2TGM + NPK	35.6	44	53.3	170.3	2.79	0.10
3TGM + NPK	34.6	43	55.3	170.3	4.43	0.10
5TGM + NPK	33.8	41	47.0	170.9	3.97	0.11
Control	37.0	42	40.6	170.6	2.32	0.11
Coeff. Var	3.51	4.61	10.94	20.55	13.07	6.60
P-value	0.001	0.001	NS	NS	0.001	NS

yield characteristics of soybean in the late and early planting seasons respectively. There were significant differences ($p = 0.05$) in the days to flowering during the early and late planting seasons. The highest days to flowering were noted for plants supplied with 3GM + P ha^{-1} (41 days) in late planting and the least for plants supplied with 5TGM + NPK ha^{-1} (32.7 days). In the early planting season, plants supplied with 5 Mg ha^{-1} of green manure had the highest days to flowering (38 days), while plants supplied with 5TGM + NPK ha^{-1} had the least (33.8 days).

There were significant differences ($p = 0.05$) in the days to 50% podding during the early and late planting seasons. The highest days to 50% podding were observed with plants supplied with 5TGM + P ha^{-1} in late planting (46 days) and 2GM + NPK ha^{-1} (44 days) in early planting seasons. The lowest days to 50% podding was noted with plants supplied with 180 Kg NPK ha^{-1} in late planting (42 days) while plants treated with 2 GM + P ha^{-1} in the early planting season had 38 days. The highest number of pods per plant was observed in plants supplied with 5 Mg ha^{-1} of green manure for both seasons (54 and 59 pods per plants respectively). The least number of pods per plant was recorded in control plants for both seasons (37 and 39 pods per plant respectively).

The weight of 1000 seeds was not significantly different with treatments in both seasons. During late and early planting seasons, the highest 1000 seed weight was noted in plants supplied with 2GM + NPK ha^{-1} (160.5 g and 180.5 g respectively). The lowest 1000 seed weight was observed with plants supplied with 180 Kg NPK ha^{-1} (140.2 g and 160.4 g respectively). The harvest index (HI) which relates the economic yield to the total dry matter yield was not significantly different for both seasons (Table 6 and Table 7). The grain yields values were significantly different in both late planting ($p < 0.001$) and early planting ($p = 0.001$) seasons. Plants supplied with 5TGM + NPK ha^{-1} had the highest grain yield in late planting (4.97 Mg ha^{-1}) while those supplied with 3TGM + NPK ha^{-1} recorded the highest grain yield during early planting (4.43 Mg ha^{-1}). The least increase was observed in control for both late and early planting seasons (2.22 Mg ha^{-1} and 2.32 Mg ha^{-1} respectively).

Table 8. Simple linear correlation coefficients of morphological growth parameters against yield.

	Grain.Y	Plt. Ht	Leaf area	Bra.No	Coll.dia	Leaf.No	Nod.No	Nod.wt
Grain.Y	1.00							
Plt.Ht	0.096	1.00						
L.area	0.004*	0.000*	1.00					
Bra.No	0.001*	0.144	0.023*	1.00				
Coll.dia	0.777	0.270	0.389	0.799	1.00			
Leaf.No	0.000*	0.680	0.431	0.296	0.374	1.00		
Nod.No	0.000*	0.214	0.074	0.028*	0.602	0.054	1.00	
Nod.wt	0.000*	0.016*	0.000*	0.000*	0.638	0.053*	0.000*	1.00

*Significant at $p = 0.05$. where: Plant height = Plt.Ht, Leaf area = L.Area, Number of branches = Bra.No, Stem collar diameter = Coll.dia, Number of leaves = Leaf.No, Number of root nodules = Nod.No, Root nodule weight = Nod.wt, Grain yield = Grain.Y.

Table 9. Simple linear correlation coefficients of flowering and podding against yield.

	Grain Y.	DF	DP
Grain Y.	1.00		
DF	0.000*	1.00	
DP	0.090	0.000*	1.00

*Significant at p = 0.05 where: DF = Number of days to 50% flowering of soybeans, DP = Number of days to 50% pod formation of soybeans, Grain Y. = Grain yield.

3.3. Correlation of Morphological Growth Parameters and Grain Yield

Results obtained for morphological growth characters (Table 8), show a positive correlation with grain yield. The correlation coefficient of grain yield with yield components shows that some measured and yield components were positively correlated to grain yield. The number of branches, leaf area, number of leaves, nodule number and nodule weight were positively and significantly related with the grain yield. 50 percent flowering, and 50% podding (Table 8) were positively correlated with grain yield. Results of the simple linear regression of grain yield on growth and yield components show that the parameters significantly contributed to grain yield (Table 9).

4. Discussion

The application of organic or inorganic fertilizers had a significant influence on the allometric growth pattern of soybean plants as compared to those without fertilization from the two weeks to about 10 weeks after sowing. This may be as a result of the nutrients supplied from the green manure and/or from other fertilizer types to boost the various physiological processes in the plant. The improvement in plant height might be due to the increased metabolic activity, stimulation of root growth resulting in increased uptake of N and P. The applications of nutrients along with green manure may have optimised the conditions for the growth of the crop which led to luxuriant growth of the plant and therefore greater plant height and biomass.

As reported by [24], manure application increased the uptake of nutrients such as P, Ca, and Mg [25]. Manure application could increase the availability of N, P, K, Mg, Na, Cu, Mn, and Zn [26]. Manure also improved the activity of enzymes present in the soils, which influenced the availability of soil nutrients both directly and indirectly [27], as well as significantly increasing plant height of soybean [28].

The high stem collar diameter and length of taproot in 5TGM + NPK or other treatment combinations might have been due to the green manure which could have improved on the soil texture and structure for easy plant growth than NPK or P treatments only. This finding corroborates that of [29] who used *Tithonia* green manure which reduced soil bulk density and therefore improved on the rooting of the crop. Similar observations were reported by [30] [31] who noted that *Tithonia* green manure enhanced soil quality for the production of cauliflower (*Brassica oleracea* var Brotrytis L).

The combination of manure and NPK fertilizer produced a better plant growth compared to that of all single inorganic fertilizer treatments since the manure added in the treatment combination may have increased the available amount of nutrients, which in turn enhanced nutrients uptake by the plants' roots. The authors [32] found that addition of manure in the NPK treatment combination improved soil fertility and while [33] reported that application of green manure increased the soil pH which may have associated with decrease of exchangeable acidity of the soil. These integrated treatments could have increased cation exchange capacity (CEC), soil enzyme activity [34], soil microbial biomass [32], enhanced nutrients uptake, increased photosynthetic rate [35]; and also increased the diversity of microorganisms that supported plant growth and development [35] [36]. The high mean number of roots nodules and nodule weight in plants supplied with green manure and P or NPK fertilizers might have been as a result of an increase in soil pH due to the reduction of exchangeable acidity, The presence of green manure could have formed organic acids which may form complexes with Fe or Al in the soil, thereby increasing the uptake of other soil nutrients and water. This invariably increases the rate of photosynthesis assuming other factors are not limiting. Similar observations were reported by [37] after the application of mulch types on a maize field in South Western Nigeria.

The reduced period of flowering and podding from the time of sowing in plants supplied with 5 Mg of green manure or NPK fertilizer only may be due to the ready availability of some plant nutrients. The green manure which also acts as mulch conserves soil moisture, thereby reducing soil temperature and also providing other nutrients not supplied by NPK fertilizer. These findings were also reported by [38] who showed that the integration of gliricidia green manure and inorganic fertilizers improved soil fertility and increased yield on Vertisols.

The grain yield for both seasons was highest in plants supplied with 3 - 5 Mg/ha plus 90 kg/ha NPK fertilizer combinations. This might be due to optimum levels of macro and micronutrients which the plants readily absorbed from the soil when compared to the plants in the control or those supplied with only single superphosphate fertilizer. This was also noted by [39] when they conjunctively supplied 50% organic fertilizer and 50% inorganic fertilizer and this increased plant growth and yield in Pampanga Province in the Philippines. Improved soybean yield resulting from manure application has also been reported from a previous study by [40].

The success of fertilizers treatments on generative growth was also reported from the previous study by [41] who found that the highest soybean yield was obtained by the application of manure + inorganic fertilizers. Another study also reported that, maximum growth and yield of wheat was achieved when the crops were fertilized with manure and inorganic fertilizer [42]. The authors [43] also reported that, the highest productivity of wheat (*Triticum aestivum* L), maize

(*Zea mays* L), and black gram (*Vigna mungo*) were obtained by combined application of organic and inorganic fertilizers. In the long term, manure and inorganic fertilizer would also be able to improve the chemical and biological components of soils [44].

The highly significant simple correlation between grain yield, leaf area, and leaf numbers illustrates that plants with large leaf surface area and greater number of leaves have increased rates of photosynthesis and part of the photosynthate is used in plant growth and productivity.

5. Conclusion

The study shows that treatment combinations of 3 - 5 Mg/ha green manure + 90 kg NPK fertilizer/ha, were the best treatments to maximize soybean productivity in the Mount Cameroon Region. NPK fertilizer provided nutrients that were readily available to the plant while the green manure played important roles in improving soil texture, soil moisture, soil organic matter and other plant nutrients that enhanced soybean productivity. Single green manure application of 5 Mg/ha could also become an alternative way to produce optimum soybean yield in the Mount Cameroon Region.

Authors' Contributions

Enow Andrew Egbe designed the study, wrote the protocol and wrote the first draft manuscript; Nkeutcha Marietta Solange Soupi did the literature review and drew the tables in the manuscript; Miranda Egbe Awo did data analysis and drew the figures in the manuscript; George Ayamba Besong collected the data from the field and processed them for data analysis. All the authors read and approved the final copy of the manuscript.

Funding

The authors contributed financially to carry out this research.

Conflicts of Interest

The authors acknowledge there is no conflict of interest.

References

[1] Westcott, P. and Hansen, J. (2016) Global Soybean Product and Trade Projections. USDA, Economic Research Service.

[2] Singh, B. and Ryan, J. (2015) Managing Fertilizers to Enhance Soil Health Managing Fertilizers to Enhance Soil Health. International Fertilizer Industry Association, Paris.

[3] Cheng, H., Hill, P.W. and Bastami, M.S. (2017) Biochar Stimulates the Decomposition of Simple Organic Matter and Suppresses the Decomposition of Complex Organic Matter in a Sandy Loam Soil. *GCB Bioenergy*, **9**, 1110-1121. https://doi.org/10.1111/gcbb.12402

[4] Rajasekar, M., Nandhini, D.U. and Swaminathan, V. (2017) A Review on Role of

Macro Nutrients on Production and Quality of Vegetables. *International Journal of Chemical Studies*, **5**, 304-309.

[5] Brar, B.S., Singh, J., Singh, G. and Kaur, G. (2015) Effects of Long-Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize-Wheat Rotation. *Agronomy*, **5**, 220-238. https://doi.org/10.3390/agronomy5020220

[6] Han, S.H., An, J.Y. and Hwang, J. (2016) The Effects of Organic Manure and Chemical Fertilizer on the Growth and Nutrient Concentrations of Yellow Poplar (*Liriodendron tulipifera* Lin.) in a Nursery System. *Forest Science and Technology*, **12**, 137-143. https://doi.org/10.1080/21580103.2015.1135827

[7] Sharma, S.B., Sayyed, R.Z. and Trivedi, M.H. (2013) Phosphate Solubilizing Microbes: Sustainable Approach for Managing Phosphorus Deficiency in Agricultural Soils. *SpringerPlus*, **2**, Article No. 587. https://doi.org/10.1186/2193-1801-2-587

[8] Gittings, S., Turnbull, N., Henry, B., *et al.* (2015) Characterisation of Human Saliva as a Platform for Oral Dissolution Medium Development. *European Journal of Pharmaceuticals and Biopharmaceutics*, **91**, 16-24. https://doi.org/10.1016/j.ejpb.2015.01.007

[9] Coban, O., Kuschk, P., Wells, N.S., Strauch, G. and Knoeller, K. (2015) Microbial nitrogen Transformations in Constructed Wetlands Treating Contaminated Groundwater. *Environmental Science and Pollution Research*, **22**, 12829-12839. https://doi.org/10.1007/s11356-014-3575-3

[10] Cole, J.C., Smith, M.W. and Penn, C.J. (2016) Nitrogen, Phosphorus, Calcium, and Magnesium Applied Individually or as a Slow Release or Controlled Release Fertilizer Increase Growth and Yield and Affect Macronutrient and Micronutrient Concentration and Content of Field-Grown Tomato Plants. *Scientia Horticulturae*, **211**, 420-430. https://doi.org/10.1016/j.scienta.2016.09.028

[11] Emsens, W.J., Aggenbach, C.J.S. and Grootjans, A.P. (2016) Eutrophication Triggers Contrasting Multilevel Feedbacks on Litter Accumulation and Decomposition in Fens. *Ecology*, **97**, 2680-2690. https://doi.org/10.1002/ecy.1482

[12] Cooper, G.D. (2017) Long-Term Effect of Tillage and Crop Rotation Practices on Soil C and N in the Swartland, Western Cape, South Africa. MSc Thesis, University of Stellenbosch, Stellenbosch.

[13] Pühringer, H. (2016) Effects of Different Biochar Application Rates on Soil Fertility and Soil Water Retention in On-Farm Experiments on Smallholder Farms in Kenya. MSc Thesis in Environmental Science, Uppsala University Sweden, Uppsala.

[14] Li, Z.Q., Zhang, X., Xu, J., Cao, K., Wang, J.H., Xu, C.X. and Cao, W.D. (2020) Green Manure Incorporation with Reductions in Chemical Fertilizer Inputs Improves Rice Yield and Soil Organic Matter Accumulation. *Journal of Soil and Sediments*, **20**, 2784-2793. https://doi.org/10.1007/s11368-020-02622-2

[15] Hou, Y.X., Hu, X.J., Yan, W.T., Zhang, S.H. and Niu, L.B. (2013) Effect of Organic Fertilizers Used in Sandy Soil on the Growth of Tomatoes. *Agricultural Sciences*, **4**, 31-34. https://doi.org/10.4236/as.2013.45B006

[16] Zhang, X.X., Zhang, R.J., Gao, J.S., Wang, X.C., Fan, F.L., Ma, X.T., Yin, H.Q., Zhang, C.W., Feng, K. and Deng, Y. (2017) Thirty-One Years of Rice-Rice-Green Manure Rotations Shape the Rhizosphere Microbial Community and Enrich Beneficial Bacteria. *Soil Biology and Biochemistry*, **104**, 208-217. https://doi.org/10.1016/j.soilbio.2016.10.023

[17] Fang, Y., Wang, F., Jia, X.B. and Chen, J.C. (2019) Distinct Responses of Ammonia-Oxidizing Bacteria and Archaea to Green Manure Combined with Reduced

Chemical Fertilizer in a Paddy Soil. *Journal of Soils Sediments*, **19**, 1613-1623. https://doi.org/10.1007/s11368-018-2154-5

[18] Kai, T., Kumano, M. and Tamaki, M. (2020) A Study on Rice Growth and Soil Environments in Paddy Fields Using Different Organic and Chemical Fertilizers. *Journal of Agricultural Chemistry and Environment*, **9**, 331-342. https://doi.org/10.4236/jacen.2020.94024

[19] Nahera, M.E., Abu, T.M.A., Choudhury, B., Biswasa, J.C., Panhwar, Q.A. and Kennedy, I.R. (2019) Prospects of Using Leguminous Green Manuring Crop *Sesbania rostrata* for Supplementing Fertilizer Nitrogen in Rice Production and Control of Environmental Pollution. *Journal of Plant Nutrition*, **43**, 285-296. https://doi.org/10.1080/01904167.2019.1672734

[20] Wazir, A., Gul, Z. and Hussain, M. (2018) Comparative Study of Various Organic Fertilizers Effect on Growth and Yield of Two Economically Important Crops, Potato and Pea. *Agricultural Sciences*, **9**, 703-717. https://doi.org/10.4236/as.2018.96049

[21] Egbe, E.A., Forkwa, E.Y. and Enow, E.A. (2014) Evaluation of Seedlings of Three Woody Species under Four Soil Moisture Capacities. *British Journal of Applied Science and Technology*, **24**, 21-31.

[22] Egbe, E.A. and Tabot, P.T. (2011) Carbon Sequestration in Eight Woody Non-Timber Forest Species and Their Economic Potentials in South-Western Cameroon. *Applied Ecology and Environmental Research*, **9**, 369-385. https://doi.org/10.15666/aeer/0904_369385

[23] Mutezo, W.T. (2013) Early Crop Growth and Yield Responses of Maize (*Zea mays*) to Biochar Applied on Soil. International Working Paper Series 13/03.

[24] Steiner, C., Teixeira, W.G., Lehmann, J., Nehls, T., De Macêdo, J.L.V., Blum, W.E.H. and Zech, W. (2007) Long Term Effects of Manure, Charcoal and Mineral Fertilization on Crop Production and Fertility on a Highly Weathered Central Amazonian Upland Soil. *Plant and Soil*, **291**, 275-290. https://doi.org/10.1007/s11104-007-9193-9

[25] Lentz, R.D. and Ippolito, J.A. (2012) Biochar and Manure Affect Calcareous Soil and Corn Silage Nutrient Concentrations and Uptake. *Journal of Environmental Quality*, **41**, 1033-1043. https://doi.org/10.2134/jeq2011.0126

[26] Guo, L., Wu, G., Li, Y., Li, C., Liu, W., Meng, J. and Jiang, G. (2016) Effects of Cattle Manure Compost Combined with Chemical Fertilizer on Topsoil Organic Matter, Bulk Density and Earthworm Activity in a Wheat-Maize Rotation System in Eastern China. *Soil and Tillage Research*, **156**, 140-147. https://doi.org/10.1016/j.still.2015.10.010

[27] Saha, S., Prakash, V., Kundu, S., Kumar, N. and Mina, B.L. (2008) Soil Enzymatic Activity as Affected by Long Term Application of Farm Yard Manure and Mineral Fertilizer under a Rainfed Soybean-Wheat System in NW Himalaya. *European Journal of Soil Biology*, **44**, 309-315. https://doi.org/10.1016/j.ejsobi.2008.02.004

[28] Devi, K.N., Singh, T.B., Athokpam, H.S., Singh, N.B. and Samurailatpam, D. (2013) Influence of Inorganic, Biological and Organic Manures on Nodulation and Yield of Soybean (*Glycine max* Merril L.) and Soil Properties. *Australian Journal of Crop Science*, **7**, 1407-1415.

[29] Piotrowska, A. and Wilczewski, E. (2012) Effects of Catch Crops Cultivated for Green Manure and mineral Nitrogen Fertilization on Soil Enzyme Activities and Chemical Properties. *Geoderma*, **189**, 72-80. https://doi.org/10.1016/j.geoderma.2012.04.018

[30] Opala, P.A. (2020) Recent Advances in the Use of *Tithonia diversifolia* Green Manure for Soil Fertility Management in Africa. A Review. *Agricultural Reviews*, **41**, 256-263. https://doi.org/10.18805/ag.R-141

[31] Hafifah, S., Maghfoer, M.D. and Prasetya, B. (2016) The Potentials of *Tithonia diversifolia* Green Manure for Improving Soil Quality for Cauliflower (*Brassicaoleracea* var. Brotrytis L). *Journal of Degraded and Mining Land Management*, **3**, 499-506.

[32] Salama, Z.A., El Baz, F.K., Gaafar, A.A. and Zaki, M.F. (2015) Antioxidant Activities of Phenolics, Flavonoids and Vitamin C in Two Cultivars of Fennel (*Foeniculum vulgare* Mill.) in Responses to Organic and Bio-Organic Fertilizers. *Journal of the Saudi Society of Agricultural Sciences*, **14**, 91-99. https://doi.org/10.1016/j.jssas.2013.10.004

[33] Lashari, M.S., Liu, X., Ji, H., Li, L., Zheng, J. and Pan, G. (2015) Changes in Soil Microbial Community Structure and Enzyme Activity with Amendment of Biochar-Manure Compost and Pyroligneous Solution in a Saline Soil from Central China. *European Journal of Soil Biology*, **70**, 67-76. https://doi.org/10.1016/j.ejsobi.2015.07.005

[34] Jannoura, R., Bruns, C. and Joergensen, R.G. (2013) Organic Fertilizer Effects on Pea Yield, Nutrient Uptake, Microbial Root Colonization and Soil Microbial Biomass Indices in Organic Farming Systems. *European Journal of Agronomy*, **49**, 32-41. https://doi.org/10.1016/j.eja.2013.03.002

[35] Zhang, Q.C., Shamsi, I.H., Xu, D.T., Wang, G.H., Lin, X., Jilani, G. and Chaudhry, A.N. (2012) Chemical Fertilizer and Organic Manure Inputs in Soil Exhibit a Vice Versa Pattern of Microbial Community Structure. *Applied Soil Ecology*, **57**, 1-8. https://doi.org/10.1016/j.apsoil.2012.02.012

[36] Hamm, A.C., Tenuta, M., Krause, D.O., Ominski, K.H., Tkachuk, V.L. and Flaten, D.N. (2016) Bacterial Communities of an Agricultural Soil Amended with Solid Pig and Dairy Manures, and Urea Fertilizer. *Applied Soil Ecology*, **3**, 61-71. https://doi.org/10.1016/j.apsoil.2016.02.015

[37] Awopegba, M., Oladele, S. and Awodun, M. (2017) Effect of Mulch Types on Nutrient Composition of Maize (*Zea mays* L) Yield and Soil Properties of a Tropical Alfisol in Southwestern Nigeria. *Eurasian Journal of Soil Science*, **6**, 121-133. https://doi.org/10.18393/ejss.286546

[38] Yadav, J., Gabhane, V.V., Sheike, A., Rathod, A., Satpute, U. and Chandel, A. (2020) Effect of Potash Management through Gliricidia Green Leaf Manuring on Soil Fertility and Yield of Soybean in Vertosols. *Journal of Pharmacognosy and Phytochemistry*, **9**, 1033-1037.

[39] Simbulan, J.C. and de Jesus, N. (2020) Response of Soybean (*Glycine max* (L.) Merill) to Organic and Inorganic Fertilizers. *Asian Journal of Applied Research and Community Development and Empowerment*, **4**, 13-17. https://doi.org/10.29165/ajarcde.v4i1.31

[40] Tagoe, S.O., Horiuchi, T. and Matsui, T. (2008) Effects of Carbonized and Dried Chicken Manures on the Growth, Yield, and N Content of Soybean. *Plant and Soil*, **306**, 211-220. https://doi.org/10.1007/s11104-008-9573-9

[41] Bandyopadhyay, K.K., Misra, A.K., Ghosh, P.K. and Hati, K.M. (2010) Effect of Integrated Use of Farmyard Manure and Chemical Fertilizers on Soil Physical Properties and Productivity of Soybean. *Soil and Tillage Research*, **110**, 115-125. https://doi.org/10.1016/j.still.2010.07.007

[42] Mandal, A., Patra, A.K., Singh, D., Swarup, A. and Masto, R.E. (2007) Effect of

Long-Term Application of Manure and Fertilizer on Biological and Biochemical Activities in Soil during Crop Development Stages. *Bioresource Technology*, **98**, 3585-3592. https://doi.org/10.1016/j.biortech.2006.11.027

[43] Sandeep, K., Vomendra, K., Thalesh, K. and Om, P.B. (2020) Effect of Organic and Inorganic Nutrient Combinations on Yield and Economics of Black Gram (*Vigna mungo* L.) *International Journal of Current Microbiology and Applied Sciences*, **9**, 3366-3371. https://doi.org/10.20546/ijcmas.2020.908.388

[44] Liu, C.A., Li, F.R., Zhou, L.M., Zhang, R.H., Yu, J., Lin, S.L. and Li, F.M. (2013) Effect of Organic Manure and Fertilizer on Soil Water and Crop Yields in Newly-Built Terraces with Loess Soils in a Semi-Arid Environment. *Agricultural Water Management*, **117**, 123-132. https://doi.org/10.1016/j.agwat.2012.11.002