Production of Bean (*Phaseolus vulgaris* L.) under Organo-mineral Fertilization in Humid Forest Agro-Ecological Zone with Bimodal Rainfall Pattern in Cameroon

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Authors’ contributions

This work was carried out in collaboration between all authors. Author SMK wrote the protocol, performed the data collection, managed the literature searches and wrote the first draft of the manuscript. Authors PPKN, DGME and WNK performed the data collection and corrected the draft manuscript. Author CNT performed the statistical analysis, corrected the research protocol and the draft of the manuscript. Authors LBT and EY corrected the research protocol and facilitated the work. All authors read and approved the final manuscript.

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ABSTRACT

Bean is an annual legume, consumed by more than 500 million people worldwide. It is a base in their daily diet because of its high protein content (25-30%). In Cameroon, its culture has many problems, including the significant decline in fertility and soil acidity. This study aimed to evaluate the effect of organo-mineral fertilization on the bean production. The experimental design was a complete randomized block with two factors [varieties (NITU and DOR 701) and treatments (T0:

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control, T1: poultry manure and T2: NPK]) and three replications. The study was carried out at the second cropping season from August to November 2015 in Eloumden in the Mefou and Akono Division, Centre Region (Cameroon). The organo-mineral fertilization of two new varieties of beans was tested. The collar diameter, the number of leaves and the shoot length were evaluated weekly. At harvest, the nodulation and yield were evaluated. The results showed that treatment with poultry manure (T1) induced a very highly significant growth ($P < .001$) of shoot length, as well as a significant increase in the number of pods (36 ± 5.91), the number of seeds (142 ± 88.07) and the biomass. The chemical fertilizer treatment (T2) induced the best nodulation (25.50 ± 0.87). The treatments did not influence the seed yield. However, the varietal effect was highly significant. DOR 701 had a higher seed yield (5.91 ± 1.03 t ha-1) than the NITU variety (4.19 ± 0.54 t ha-1). Poultry manure (T1) restores the minerals useful for the next crop. It is therefore recommended because of its best yield and its ability to protect the environment.

Keywords: Cameroon; chicken manure; common bean; NPK; yield.

1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an annual plant native to Latin and Central America where it has been domesticated for more than 8,000 years [1]. Consumed by nearly 500 million people worldwide, it is a staple food in their daily diet because of its high protein content (25-30% of the dry seed) [2]. According to FAO statistics, world average dry bean consumption has been estimated at 2.2 kg capita-1 year-1, with wide variations across continents [3]. In Cameroon, common bean is the third most widely consumed legume after groundnut and cowpea [4]. World dry bean production, according to FAO statistics, increased from 28.6 million tons in 2006 to 24.6 million tons in 2013 [5], of which 200 000 tons is produced by Cameroon (17th world producer) out of a total of 230 000 hectares representing a yield of 870 kg ha-1. This national production remains low [6].

The low resources and the fragility of soils found in developing countries are the main limiting factors in agricultural productivity [7]. Among them, the acidity of tropical soils and their nutrient deficiencies including phosphorus and particularly the most common factors [7-11]. These poor soils become unable to produce a good yield after one, two or three crops. According to the International Center for Soil Fertility and Agricultural Development (IFDC), Africa loses 8 million metric tons of soil nutrients each year and more than 95 point of reducing significantly productivity [12].

Various solutions have been proposed to solve this problem. Chemical fertilizers are used to provide plants with one or more mineral elements that are lacking on the soil or that are present in an insufficient amount, or in the non-assimilable form [7,13]. But, most of the farmers inadequately apply fertilizers above the recommended doses to increase the yields, leading to a long-term increase in soil acidity and the degradation of its physical status [14]. For many poor farmers, Biological Nitrogen Fixation (BAF) is a sustainable, cost-effective or a complementary solution to industrial nitrogen fertilizer [7]. The work carried out by [15] showed that the use of organic amendments in the restoration of soil fertility is particularly appropriate. These maintain the physicochemical properties and soil fertility [9,13,15]. They conserve natural resources, protect the environment and are cheaper than chemical fertilizers [9,15]. Many studies are still being conducted on soil fertility options for intensification of bean production [7]. The effect of organo-mineral fertilization on the improvement of bean production remains little known. The objective of this study is to evaluate the effect of organo-mineral fertilization on the bean production.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Study area

The experiment took place in the field, in the Centre Region, Mefou and Akono Division, Bikoh Sub-division; Eloumden locality (3°49’128”N- 0110 26’553”E) (Fig. 1), during the second cropping season in 2015. The area is characterized by a bimodal rainfall pattern with four seasons: two rainy seasons and two dry seasons. The climatic data recorded during the experimental period showed an average precipitation of 235 mm/day, an average daily temperature of 23.5°C and average sunshine of 15 hours.
The physicochemical analyses of the soil and the poultry manure were carried out before the soil preparation at the Laboratory of Analysis, of Soils, Plants, Waters and Fertilizers (LAPSEE) of IRAD (Institute of Agricultural Research for Development) at Nkolbisson. Soil samples were air-dried and ground to pass through a 2 mm sieve. For carbon (C) and nitrogen (N) analysis, the samples were finely ground to pass through a 0.5 mm sieve. pH was determined in a 1:2.5 (w/v) soil: water suspension. Organic C was determined by chromic acid digestion and spectrophotometric analysis [17]. Total N was determined from a wet acid digest and analyzed by colorimetric analysis [18]. P was extracted using Bray extractant and the resulting extract analyzed using the molybdate blue procedure [19]. Exchangeable cations (Ca, Mg, K and Na) were extracted using the ammonium acetate (NH₄OAC, pH: 7) and determined by flame atomic absorption spectrophotometry. Cation exchange capacity (CEC) was determined using ammonium acetate. The soil of the experimental site was acidic, low in organic carbon content and poor in the exchangeable base (Table 1). Poultry manure was rich in N and P (Table 2).

### Table 1. Soil characteristics of experimental site

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay (%)</td>
<td>39.26</td>
</tr>
<tr>
<td>Coarse sand (%)</td>
<td>22</td>
</tr>
<tr>
<td>Fine silt (%)</td>
<td>2.65</td>
</tr>
<tr>
<td>Coarse silt (%)</td>
<td>6.51</td>
</tr>
<tr>
<td>Fine sand (%)</td>
<td>50.10</td>
</tr>
<tr>
<td>Organic Matter (g.kg⁻¹)</td>
<td>2.75</td>
</tr>
<tr>
<td>Organic Carbon (g.kg⁻¹)</td>
<td>1.60</td>
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<tr>
<td>Total nitrogen (g.kg⁻¹)</td>
<td>0.16</td>
</tr>
<tr>
<td>Available P (mg.kg⁻¹)</td>
<td>3.60</td>
</tr>
<tr>
<td>Calcium (mol.kg⁻¹)</td>
<td>1.35</td>
</tr>
<tr>
<td>K⁺ (mol.kg⁻¹)</td>
<td>0.06</td>
</tr>
<tr>
<td>CEC (mol.kg⁻¹)</td>
<td>6.50</td>
</tr>
<tr>
<td>pH water</td>
<td>6.50</td>
</tr>
<tr>
<td>pH KCl</td>
<td>5.98</td>
</tr>
</tbody>
</table>

#### 2.1.2 Plant material

The plant material used from IRAD of Foumbot consisted of two varieties of beans (Fig. 2), namely:
- NITU which is an improved variety, popularized by the IRAD in 2012. It has a dwarf port, a very short cycle (65-70 days), a yield of 2 - 2.5 t / ha and is adapted to the agro-ecological zones III, IV and V [20, 21];
- DOR 701 which is an improved variety of beans, popularized by IRAD in 2012; it has CIAT/ PABRA origin, it also has a type of semi-climbing growth, a cycle ranging from (80 - 90 days), a yield of 2 - 3 t / ha, a red color and is suitable for agro-ecological zones III, IV and V [20, 21].

2.2 Experimental Design

The experimental set-up was a completely randomized block design with two factors:

Fertilizers [T0: Control, T1: Poultry manure (20 tonnes.ha-1), T2: NPK (225 kg.ha−1 of NPK (14%N-24%P2O5-14%K2O)], and T3: poultry manure (50% T1 + NPK (50% T2)] and varieties (V1: NITU and V2: DOR 701). In total, twenty-four experimental units of 2 m² (2 m x 1 m) were organized in three blocks spaced 0.5 m each.

Table 2. Physicochemical characteristics of poultry manure

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content (%)</td>
<td>20.48</td>
</tr>
<tr>
<td>pH water</td>
<td>7.91</td>
</tr>
<tr>
<td>N (g.kg⁻¹)</td>
<td>23.59</td>
</tr>
<tr>
<td>P (g.kg⁻¹)</td>
<td>48.47</td>
</tr>
<tr>
<td>K (g.kg⁻¹)</td>
<td>4.58</td>
</tr>
</tbody>
</table>

2.3 Sowing and Amendment

Bean was sowed at the rate of four (04) seeds per hole following a 50 x 40 cm pattern for DOR 701 variety and 50 x 30 cm pattern for NITU variety, at a depth of 3 to 4 cm. The poultry manure was applied at 20 tonnes.ha-1 [14,22-23] on experimental plots two weeks before sowing. Four (4) and 2 kg/experimental unit (2 m²) of poultry manure was applied to T1 and T3 respectively. The mineral fertilizer NPK (14%N-24%P2O5-14%K2O) was applied at 225 kg.ha-1 [20] on experimental plots two weeks after sowing. 40 and 20 g/ experimental unit (2 m²) of 14-24-14 were applied to T2 and T3 respectively. Manual weeding was done as required. The seed emergence rate was evaluated at 2, 4, 6, 8, and 10 days after sowing (DAS) for each of the two common bean varieties using the following formula:

Rate of sprouting (%) = \( \frac{\text{Number of sprouted seeds}}{\text{Number of seeds sown}} \times 100 \).

2.4 Data Collection on Agronomic Parameters

Agronomic growth parameters, shoot length, a number of leaves, collar diameter and pod number, were taken weekly from the third week after showing up to the end of heading stage. At the full bloom stage of the bean, four (4) plants were collected within each experimental unit. Two plants per line on opposite sides of the two inner and outer lines were delicately uprooted to

Fig. 2. Beans varieties
A: NITU, B: DOR 701
assess nodulation (number of nodules, fresh and dry weights) and dry root biomass. The shoot of the sampled plants was used to evaluate the above-ground biomass. Seed yield was determined at harvest. The plant samples taken were put into labelled envelopes and transported to the laboratory for the various measurements. The fresh biomass was measured using a SARTORIUS brand precision balance. Shoot dry biomass was weighed after drying in an oven at 60°C for 72 h [24]. The dry matter content (DM) was obtained by the following formula:

\[ \text{DM (\%)} = \left( \frac{\text{DW}}{\text{FW}} \right) \times 100 \]

With DM: Dry matter weight; FW: Weight of fresh material; DW: Dry weight.

The yield of dry seeds was determined by weighing dry seeds obtained using a precision electronic balance according to the following formula:

\[ \text{Yield (t.ha}^{-1}) = \frac{\text{Wgr (g)} + 10.000 \text{ (m}^3) \times 1 \text{ kg} \times 10^{-3}}{\text{NH} \times \text{SD (m}^3)} \]

[25].

Where, Wgr: Weight of grain, NH: Number of Hole Harvested and SD: Seed Density.

2.5 Data Analysis

The data collected were treated by an analysis of variance (ANOVA) using MINITAB software version 16. The means were compared using the Student Newman Keuls test at the 5% threshold. The correlation between bean productivity parameters was made using Pearson correlation coefficients.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Influence of organo-mineral fertilization on bean growth

Shoot length increased significantly \((P < .05)\) over the time (Fig. 3). Treatment with poultry manure (T1) results in a very highly significant \((P < .001)\) increase in shoot length of bean from third to the sixth week after sowing compared to others treatments (T0, T2 and T3). The control (T0) and NPK (T2) treatments induced a weak growth in shoot length in the NITU variety. In DOR 701, the similar effect was rather observed in the T3 and T2 treatments.

The different treatments were very significantly influenced by the number of leaves of the two varieties over the time (Fig. 4). There was a very highly significant \((P < .001)\) increase in the number of leaves in T3 (poultry manure + NPK) and T1 (poultry manure) treatments in the NITU and DOR 701 varieties compared to the others treatments (T0, T2 and T1).

The different treatments significantly influenced the growth of the collar diameter over the time (Fig. 5). Treatment with poultry manure (T1) resulted in a very highly significant increase \((P < .001)\) in bean collar diameter compared to others treatments (T0, T2 and T3) in the NITU variety.

![Fig. 3. Influence of organo-mineral fertilization on shoot length of beans](image)

T0: control; T1: poultry manure; T2: NPK (14-24-14); T3: 50%T1+ 50%T2
3.1.2 Influence of organo-mineral fertilization on nodulation and dry matter content of beans

The different treatments had a significant effect ($P < .05$) on the number of nodules (Fig. 6) produced in both varieties of beans. The control (T0) plant had the lowest number of nodules compared to other treatments (T1, T2 and T3). The chemical fertilizer (T2) leads to a significant production of nodules compared to other inputs (T1: poultry manure and T3: NPK + poultry manure) (Table 3). There was a significant difference in the production of nodules of 40% in T1 and 21.27% in T3 compared to T2.

The dry matter contents obtained as a result of the various fertilization treatments were not
3.1.3 Influence of organo-mineral fertilization on yield of beans

The yields obtained as a result of the different fertilization treatments were not significantly different from each other (Table 3). The statistical analysis of the number of seeds and pods obtained showed a significant difference between the treatments. Poultry manure (T1) treatment produced more pods and had more grain than other treatments.

3.1.4 Influence of varieties on growth and yield of beans

A very highly significant difference was observed between varieties. From the third to the fifth week, the NITU variety had a longer shoot length than the DOR 701 variety (Fig. 7A). But, from the fifth to the eighth week, the variety DOR 701 had a longer shoot length than the NITU variety. From the fifth week to the eighth, the variety DOR 701 had a higher number of leaves than the variety NITU; with a difference of 20 leaves (Fig. 7B). Statistically, the two varieties did not show the difference for the collar diameter up to seven weeks of growth (Fig. 7C).

Table 3. Influence of organo-mineral fertilization on nodulation, dry matter, yield components and yield of beans

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Treatment</th>
<th>Number of nodules</th>
<th>Dry matter content of nodules (%)</th>
<th>Dry matter content of plant (%)</th>
<th>N° of pod</th>
<th>N° of seed</th>
<th>Yield (t.ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitu</td>
<td>T0</td>
<td>5.17 d</td>
<td>2.53 a</td>
<td>1.93 ab</td>
<td>7 b</td>
<td>23 b</td>
<td>3.19 b</td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>13.00 c</td>
<td>3.12 a</td>
<td>2.90 a</td>
<td>29 ab</td>
<td>57 b</td>
<td>4.36 b</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>25.50 a</td>
<td>2.76 a</td>
<td>1.96 ab</td>
<td>11 b</td>
<td>41 b</td>
<td>4.71 b</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>19.53 b</td>
<td>3.33 a</td>
<td>1.89 b</td>
<td>14 b</td>
<td>50 b</td>
<td>4.53 b</td>
</tr>
<tr>
<td>Means Nitu</td>
<td>T0</td>
<td>15.80 A</td>
<td>2.94 A</td>
<td>2.17 A</td>
<td>15.2 B</td>
<td>42.75 B</td>
<td>4.05 B</td>
</tr>
<tr>
<td>Dor 701</td>
<td>T1</td>
<td>15.50 bc</td>
<td>3.60 a</td>
<td>1.71 b</td>
<td>36 a</td>
<td>142 a</td>
<td>6.63 a</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>22.13 ab</td>
<td>2.25 a</td>
<td>2.22 ab</td>
<td>19 ab</td>
<td>97 ab</td>
<td>5.93 a</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>18.10 b</td>
<td>2.52 a</td>
<td>1.95 ab</td>
<td>19 ab</td>
<td>91 ab</td>
<td>5.66 a</td>
</tr>
<tr>
<td>Means Dor</td>
<td>Varieties (V)</td>
<td>16.18 A</td>
<td>2.64 A</td>
<td>2.03 A</td>
<td>24 A</td>
<td>97.3 A</td>
<td>5.91 A</td>
</tr>
<tr>
<td></td>
<td>Treatment (T)</td>
<td>***</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
<td>**</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>T*V</td>
<td>***</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

T0: control, T1: poultry manure, T2: NPK 14-24-14, T3: 50% T1+50% T2. Values followed by the same letter are not significantly different. *: P = .05, **: P < .01, ***: P < .001

Fig. 7. Influence of the variety on the growth of beans
A: shoot length, B: number of leaves, C: collar diameter
Globally, highly significant differences ($P < .001$) were observed between varieties. Thus, DOR 701 variety produced more pod and seed than NITU (Table 3). The DOR 701 variety gave a better beans yield than the NITU variety, a surplus of one tons (Table 3). But, there was no significant difference between the both for the nodulation and dry matter produced (Table 3).

3.1.5 Correlation

Analysis of the correlation table between the measured and evaluated parameters related to the productivity of common bean showed that most were not significantly correlated (Table 4). Only three (3) of these correlation coefficients showed that some of these variables were very significantly ($P < .001$) correlated. Thus, the number of leaves per plant was positively and strongly correlated ($r = 0.789$ ****) to the shoot length. There was also a positive and strongly significant correlation between the seed yield and the shoot length ($r = 0.630$ ***), and between the seed yield and the number of leaves ($r = 0.694$ ***).

3.2 Discussion

Treatment with poultry manure generally showed better growth of the plant in both common bean varieties, starting from the fourth week. This result is probably attributed to its slow mineralization to provide the mineral elements to soils and crops. Similar results were obtained by [26] with household waste compost on a ferralsol from Kinshasa using peanut, soybean and sorrel as a test crop. Organic matter plays an important role in the soil, proving favorable for the growth of microorganisms that induce an activation of nutrient solubilization. Nutrients made sufficiently available over time in the soil are effectively used by crop plants [9,27, 28].

The low plant performance observed on control soils can be attributed to nutrient deficiencies (Ca, P, K) [8,29-31]. Organic matter, therefore, allows the recycling of nutrients and the regulation of plant nutrition. This result is confirmed by those of many studies [9,32].

NPK 14-24-14 fertilizer leads to a significant production of nodosities compared to the poultry manure and the combination NPK + poultry manure. This important presence of nodules in the NPK 14-24-14 treatment is due to the richness of this fertilizer in phosphorus (P). Temegne et al. [33,34] found that soluble P significant increase in the number of nodules of Bambara bean. Indeed, a sufficient P supply promotes nodulation and consequently the plant’s growth [35]. This result also corroborates with that of [36], who worked on the determination of the nodulation capacity of some bean lines in the Middle West of Madagascar, and could show that the low level of soil phosphorus reduces nodulation. The low production of nodules noted in the treatment with poultry manure is due to the high content of nitrogen elements. Studies have already shown that over-fertilization of nitrogen elements negatively influences nodulation [9,37].

The study of the correlations between dry matter content of nodules and yield did not reveal a statistically significant correlation. Thus, it is possible to say that the presence of nodules did not have an effect on the yield of the bean. [36] deduced that the presence of nodules does not imply necessarily the fixation of the nitrogen. The obtained result seems

<table>
<thead>
<tr>
<th>SL</th>
<th>NL</th>
<th>CD</th>
<th>NN</th>
<th>DMCN (%)</th>
<th>DMCB (%)</th>
<th>Yield (t/ha-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Correlation matrix of the measured variables on beans varieties between shoot length (SL), number of leaves (NL), collar diameter (CD), number of nodule (NN), dry matter content of beans (DMCB), dry matter content of nodule (DMCN) and yield

<table>
<thead>
<tr>
<th>SL</th>
<th>NL</th>
<th>CD</th>
<th>NN</th>
<th>DMCN (%)</th>
<th>DMCB (%)</th>
<th>Yield (t/ha-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.789***</td>
<td>1</td>
<td>0.180ns</td>
<td>0.166ns</td>
<td>1</td>
<td>0.023ns</td>
</tr>
</tbody>
</table>

* * ** Significant at .05, .01 and .001 probability levels, respectively; ns: indicates no significant difference was observed at .05 probability level
contrary to those of [38] who showed that the association of beans with rice cultivation was sustainable. In such situations, inoculation of bean seeds with efficient and competitive strains of Rhizobium will be required at sowing time.

The study of correlations revealed a positive and very highly significant correlation between the yield, the shoot length and the number of leaves (N leaves) respectively. This result suggests that seed yield is related to the number of leaves and the shoot length. Indeed, the plant height and the number of leaves are excellent indicators of the rate of growth of the plant. The number of leaves influences the yield, thanks to the role played by the leaves in photosynthesis and consequently in the accumulation of reserves [37].

The climbing variety (DOR 701) had a higher yield (5.9 ± 1.03 t ha⁻¹) compared to the NITU variety (4.19 ± 0.52 t ha⁻¹), with a difference of one tonne. The influence of the variety on yield has already been reported by several authors on different types of crops such as cowpea, soybean, Bambara bean or corn and even on beans [8,10,31,39-40]. In most cases, improved varieties have a particular characteristic such as disease resistance, salt tolerance, drought tolerance, improved ability to acquire major nutrients, which are the most effective [10,33].

4. CONCLUSION

The objective of this research was to evaluate the effect of organo-mineral fertilisation on the production of two varieties of bean (Phaseolus vulgaris L.). It appears that the yield and the dry matter contents of the nodules obtained between the treatments are statistically identical. However, poultry manure was more successful than the chemical fertiliser used (NPK 14-24-14) on growth parameters (shoot length, collar diameter, number of leaves). The DOR 701 variety gave the best yield (5.91 ± 1.03 t ha⁻¹) compared to the NITU variety (4.19 ± 0.54 t ha⁻¹). This investigation shows that it is possible to grow beans without the use of chemical fertilisers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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