Original Research Article

Effect of pyroclastic powder on the growth and seeds nutritional values of common bean (*Phaseolus vulgaris* l.) on ferralitic soils in Adamawa (Cameroon, Central Africa)

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ABSTRACT

Aims: Amendment of ferralitic soils of Ngaoundere (Cameroon) by rock materials, so-called petrofertilizer, can be a promising solution to improve their fertility and thus enhance crop yield.

Study design: In the present study, the influence of pyroclastic powder on the growth of the common bean (Phaseolus vulgaris L.) was assessed.

Place and Duration of Study: Department of Biological Sciences. The sowing was done on June 13, 2017 until 2 septembre.

Methodology: An experimental design with four (04) different treatments was implemented: 0 g per pot (0% of pyroclastic: the control), 150 g per pot (10% of pyroclastic: P10 Treatment), 300 g per pot (20% of pyroclastic: P20 Treatment) and 450 g per pot (30% of pyroclastic: P30 Treatment). The pyroclastic powder was applied at three different (03) stages: sowing, germination, and flowering stage. All the treatments were irrigated with 250 ml of water once every 3 days during the growing stage.

Results: Growth parameters, seed yield, and seeds nutritional values were measured. Results revealed that seeds yield from the treated pot using 30% of pyroclastic powder is 4.2 times greater than that of the control. Globally, pyroclastic powder improved the nutritional values of common bean seeds compared to the Control. Fertilizing the soils at the sowing stage significantly ($p<0.05$) improves the values of the studied growth parameters. The protein content of seeds from treatment at the sowing stage was 1.05 and 1.11 times greater than that from treatment at germination and flowering stages.

Conclusion The application of 30% of pyroclastic powder at the sowing stage is recommended for the cultivation of the common bean in the Adamawa (Cameroon).

Keywords: *Phaseolus vulgaris L., pyroclastic powder, growth, seeds, nutritional values, ferralitic soils, Adamawa*

1. INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is one of the most important legume crops worldwide, due to its high content of complex carbohydrates, fiber, and protein. P. vulgaris is an important component of subsistence agriculture grown worldwide over an area of about 28.78 million hectares with an annual production of 23.14 million tons [1] and feeds about 300 million people in the tropics and 100 million people in Africa alone. In addition, it is becoming an important source of income, especially in Cameroon where the cultivation of this legume is anchored in the minds of the farmers [2]. The common bean is an annual legume that well adapts to diverse environments and elevations ranging from sea level to 3000 m height [3], and in areas with average annual rainfall ranging from 500 to 1500 mm. It is not drought resistant; it ideally requires moist soil throughout the growing season [4]. This crop grows preferentially on neutral or slightly alkaline soils [5] and is very sensitive to the lack of minerals and salinity. This is why acid ferralitic soils such as those of Adamawa (Cameroon) are not suitable for its growth. Taking into account the nutritional importance of this plant, it is, therefore, necessary to solve the fertility problem of Adamawa soils, to improve the P. vulgaris productivity. Adamawa farmers most often use chemical fertilizers for common bean cultivation. However, the use of chemical fertilizers presents an immediate beneficial effect on crop growth and provides an immediate solution to solve fertility problems, but their high cost and unavailability make them almost inaccessible to small farmers. In addition, its exclusive use causes serious environmental damage [6, 7]. In this context, the introduction of low-cost agricultural practices aimed at increasing agricultural production and based on the respect for ecological functionalities is necessary [6]. Scientific research recommends adapting strategies based on the use of organic fertilizers [8, 6, 9] and geological materials for remineralization of depleted soils [10,11].

In this context, the study of the effect of vivianite powder on common bean growth in the Dang locality (Adamawa Cameroon) found that this mineral fertilizer improves growth and seed yield [2]. However, the region of Adamawa Cameroon abounds in other geological materials such as pyroclastic that can be used in agriculture. The use of basaltic pyroclastic powder for common bean cultivation in the Adamawa region of Cameroon would solve the problem of soil deficiency in mineral elements, improve the growth potential of this legume, and valorize the local material available in agriculture while protecting the environment. The pyroclastic powder is rich in exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) [12] and it abounds around Lake Tyson in Adamawa-Cameroon.

This study aimed to sustainably improve the common bean productivity in Adamawa Cameroon by using basaltic pyroclastic powder as petrofertilizer. Specifically, this work aims to evaluate (1) the suitable concentration of pyroclastic powder for common bean productivity; (2) the suitable period of application of pyroclastic powder for common bean growth, and (3) to analyze seed nutritional values improvement.

2. MATERIAL AND METHODS

2.1. Experimental area

The study was conducted during cropping season in 2017 within the biodiversity and sustainable development laboratory of the University of Ngaoundere (Cameroon). The area belongs to the agro-ecological zone II of Cameroon and it is characterized by a Sudano-Guinean savannah with five months of the dry season (November to March) and seven months of the rainy season (April to October). The average annual temperature and total annual precipitations are 25.75°C, and 1.898.6 mm [13] respectively. The geographical parameters of the field are 7 ° 25 ' 119 "East latitude, 08°20'806" North longitude, and 1106 m altitude. The vegetation of the area is an herbaceous savannah dominated by *Imperata cylindrica, Pennisetum purpureum, Annona senegalensis, and Piliostigma thonningii*. The Adamawa Region is characterized by 3 major hydrographic systems namely: The Atlantic basin with the South Vina, the Lake Chad Basin, and finally the Niger basin [14].

2.2 Biological Material

Seeds of GLP 190 variety of *Phaseolus vulgaris* of Ngaoundere (Cameroon) town were used (Fig. 1). This common bean variety was chosen for its great adaptability to the rainy season and its short reproduction cycle (55-65 days). Using plants with a short reproduction cycle is an advantage for farmers in that they may have several harvests per year if they have off-season crop methods [15].

Fig. 1: *Phaseolus vulgaris* seed of GLP 190 variety

2.3 Pyroclastic powder

The pyroclastic powder was used as petrofertilizer (Figs. 2a & b). It was sampled around Lake Tyson in Ngaoundere, Cameroon. The pyroclastic was powdered with a hammer and then this powder was sieved (0.3 mm) before using it in the experiment.

Fig. 2: Pyroclastic rock from Tyson Lake before (a) and after sampling (b)

2.4. Growing soil

The growing soil is from a mango orchard out in Bini-Dang (Ngaoundere, Cameroon). This soil was dug at 20 cm depth. The moisture content of growing soil was measured according to the Association of Official Analytical Chemists [16]. Soil samples (5 g) were weight in a crucible and submitted to oven-drying at 105^{o} C until obtaining a constant weight. pH was measured using a pH meter (Model ORION 230A – Range – 2 – 19.99 ± 0.01, USA). Total Organic Matter was determined by samples calcination in the oven at 550°C according to AFNOR [17] and the residual ash was used for some mineral determination. Total nitrogen content was determined after the mineralization of samples according to the Kjeldahl method [18] and the dosage was carried out according to a calorimetric analysis by the Association of Official Analytical Chemists [19]. Assessment of calcium and magnesium was carried out by titration with Ethylene diamine tetraacetic acid [20].

The growing soil's chemical properties before the experiment are presented in Table 1. The soil was slightly acidic (5.96) and rich in Organic Matter (15.23 %). The high level of organic matter (OM) content was explained by the fact that the soil was sampled in an orchard. Indeed, soils from agroforestry systems (orchards and house gardens) are rich in Organic Matter due to the decomposition of the litter of trees. The electrical conductivity which determines the degree of salinity showed that the soil was unsalted [20]. The C / N ratio obtained showed that the microbial activity of the soil was too fast. The soil was very poor in mineral elements (Ca, Mg, P). Output the high level of Organic Matter, conductivity, and microbial activity, the Bini-Dang soils display limiting factors for the cultivation of common beans. Basaltic Pyroclastic powder, due to its interesting content of exchangeable base made it possible to correct its defects [21].

Table 1: Soil chemical properties

Parameters	Results
pH	5.96
H (%)	12.41
EC (µs/cm)	54.60
OM (%)	15.23
C (%)	8.70
N (%)	1.43
C/N	6.08
Ca (%)	0.28
Mg (%)	0.36

OM: Organic Matter; **H**: humidity; **EC**: Electrical conductivity; **C**: Carbon; **N**: Nitrogen; **Ca**: Calcium; **Mg**: Magnesium

2.5. Assessment of suitable level and a suitable period of application of pyroclastic powder for common bean growth

2.5.1. Sowing and experimental designs

The sowing was done on June 13, 2017. Each experimental pot was filled with 1.5 Kg of air-dried soil. Two seeds were sown per pot at 3 cm depth. To evaluate the best concentration and the appropriate period of application of pyroclastic powder on common bean growth and development, an experimental design with four (04) different treatments of pyroclastic powder: 0 g per pot (0% of pyroclastic: the control), 150 g per pot (10% of pyroclastic), 300 g per pot (20% of pyroclastic) and 450 g per pot (30% of pyroclastic)) and Three (03) different periods of application of pyroclastic powder (sowing, germination, and flowering stage) were used with 20 repetitions. The space between two consecutive plants was 30 cm.

2.5.2. Studied parameters

The stage of plant development was evaluated. Sowing was done on June 13, 2017. Each experimental pot was filled with 1.5 Kg of air-dried soil. Two seeds were sown per pot at 3 cm depth. Thinning took place 14 days after sowing, leaving only one germinated plant in each pot. To evaluate the best concentration and the appropriate period of application of pyroclastic powder on common bean growth and development, an experimental design with four (04) different treatments of pyroclastic powder: 0 g per pot (0% of pyroclastic: the control), 150 g per pot (10% of pyroclastic), 300 g per pot (20% of pyroclastic) and 450 g per pot (30% of pyroclastic)) and Three (03) different periods of application of pyroclastic powder (sowing, germination, and flowering stage) were used with 20 repetitions. The common bean plant height and number of leaves per plant were evaluated at regular intervals of 10 days after sowing. The flowering, the leaf area, the diameter of the stem at the collar, and plant biomass were measured. At the maturity, seed yield was evaluated.

The leaf area was determined according to Erkut et al. [22] using this formula: SF = 0.67* (L1*W1) + (L2*W2) + (L3*W3), where SF = leaf area; L1 = length of leaf blade 1; L2 = length of leaf blade 2; L3 = length of leaf blade 3; W1 = maximum width of leaf blade 1; W2 = maximum leaf blade width 2 and W3 = maximum leaf blade width 3. Maximum leaflet width (W) (at the widest point perpendicular to the midrib) and length (L) (from lamina tip to the point of petiole intersection along them).

The diameter of the stem at the collar was evaluated using a caliper 0.01 mm precision and the dry biomass was evaluated according to AFNOR [17]. The amount of Nitrogen uptake by efficient nodules was estimated according to F. Ganry [23]. The seed yield (kg/ha) was estimated according to Soltner [24] cited in [25].

2.5.3. Physico-chemical parameters of P. vulgaris seeds

The weight of the seeds was evaluated on 10 seeds by treatment on a Denver brand precision scale (1/100). The protein content (N × 6.26) was determined according to AOAC standards [19]. Carbohydrates and fats content were determined by the appropriate methods. Calcium and magnesium content was measured by standard methods after incineration of common bean seed powders.

2.5.4. Statistical data analyzes

Statistical data analyzes were performed by Stratigraphic plus version 5.0 software. The results were processed by the analysis of variance (ANOVA) at the 5% threshold and optionally the means were compared by the Duncan test. The correlation between the parameters was carried out using the correlation test.

3. RESULTS AND DISCUSSION

3.1. Levels of pyroclastic powder on common bean growth, seeds yield, and seeds nutritional values

3.1.1. Plants Height

There was a significant difference (p<.05) between the plants treated with pyroclastic powder compared to the control plants (Fig. 3). At 70 Days After Sowing (DAS), the P30 treatment recorded the highest average height (23.71±1.55 cm) and the Control the lowest height (15.68±1.18 cm). The height of treated common bean plants with pyroclastic powder was significantly higher (p <.05) than that of the control. At 70 DAS, the treatment with 30% of pyroclastic powder (P30) increased plant height by 51% compared to the Control. These results are consistent with those of [26] on the use of volcanic rock powder for the remineralization of ferralitic soils. They report that the application of pyroclastic powder increased the height of corn. This increase could be linked to the combined action of the improvement of soil properties and the release of nutrients by basalt pyroclastic powder [12, 26].

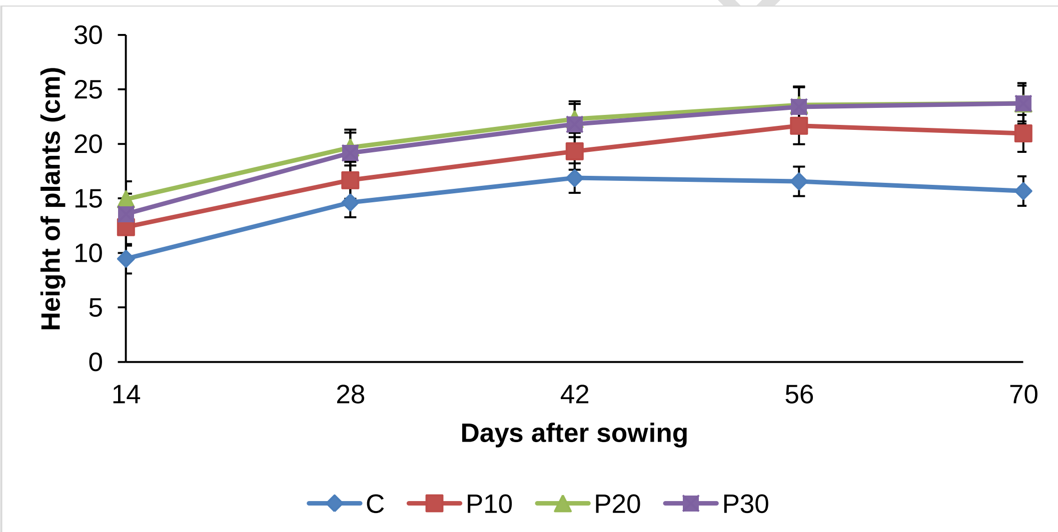

Fig. 3: Height evolution of plants depending on the treatment

C: 0% of pyroclastic powder per pot (Control), P10: 10% of pyroclastic powder per pot, P20: 20% of pyroclastic powder per pot, P30: 30% of pyroclastic powder per pot

3.1.2. Number of leaves

The analysis of variance showed that there is a significant difference between the different treatments (p <.05) on the average number of leaves per plant at maturity (Fig. 4). Indeed, at 70 days after sowing, the number of leaves per plant of common bean from a pot with 30% of pyroclastic powder is 03 times greater than that from the control pot. The highest number of leaves is recorded for the P30 treatment (7.90±1.75) and the lowest number of leaves for the Control (2.67±1.15).

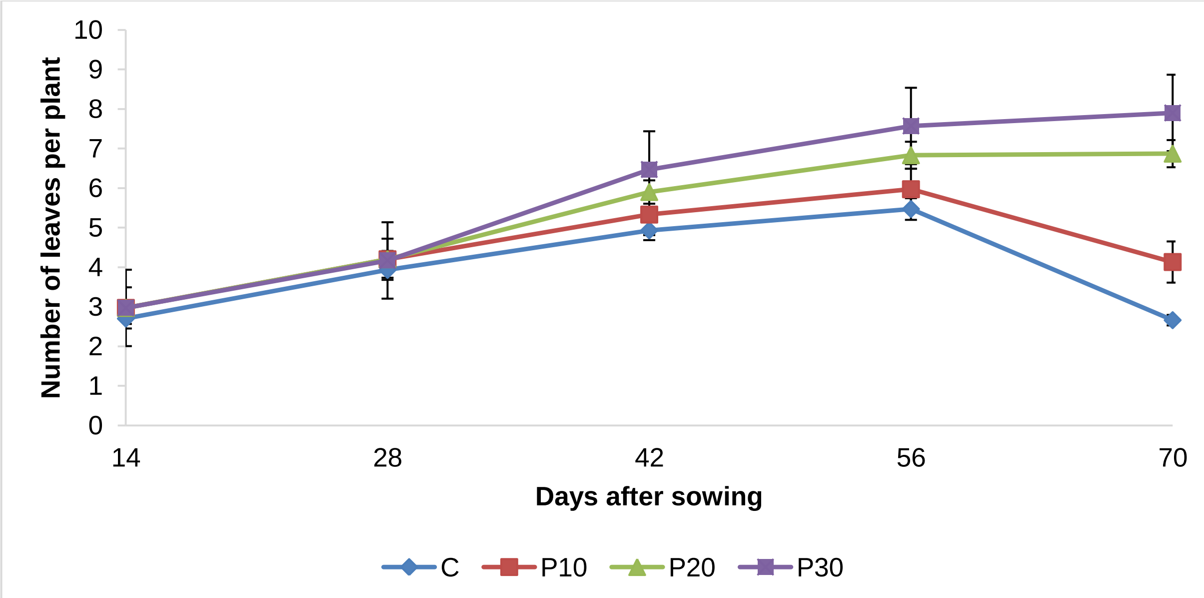

Fig. 4: Evolution of the leaves number depending on the treatment

C: 0% of pyroclastic powder per pot (Control), **P10**: 10% of pyroclastic powder per pot, **P20:** 20% of pyroclastic powder per pot, **P30:** 30% of pyroclastic powder per pot

3.1.3. Leaf area

The analysis of variance applied to the results showed that there is a significate difference ($p < .01$) between all the treatments (Table 2). All treatments with pyroclastic powder showed a leaf area greater than the Control. It is noted that the highest leaf area is obtained with the P20 treatment (71.39±0.62 cm^2) and the lowest by the Control (33.79±1.12 cm^2). The plant leaf area of the P20 treatment is 2.10 times greater than that of the control. These results are similar to those of [11] who reported that the addition of vivianite powder increased the number of leaves of *P. vulgaris* compared to the Control.

3.1.4. Diameter of stem at the collar

The application of the pyroclastic powder had no significant influence on the diameter of the stem at the collar of the plants. The analysis of variance showed that there is no significant difference ($p > .05$) between the diameter of the stem at the collar of the plants according to the treatment (Table 2).

3.1.5. Biomass of leaves, roots, and nodules

Globally, the biomass of leaves, roots, and nodules from the control was significantly ($p < .05$) less than those from treatments with pyroclastic powder (Table 2). Furthermore, P30 treatment increased the biomass of leaves and roots by 50.74% and 71.90% respectively compared to the control. The P30 treatment presented higher biomass of nodules (0.71 ± 0.05 g) while the control showed the lowest value (0.05 ± 4.36 g). The values of dry biomass obtained in this study are lower than the data reported by [8]. Indeed, this author reported that the biomass of nodules ranged from 0.02 to 0.45 g per plant.

Table 2: Effect of the dose of pyroclastic on the leaves, roots and nodules biomass of common bean plant

Treatments	C	P10	P20	P30
LA (cm²)	33.79 ± 1.12 ^{a}	51.17 ± 0.28 ^{b}	71.39 ± 0.62 ^{d}	65.00 ± 0.80 ^{c}
DC (cm²)	3.45±0.58 ^{a}	3.52±0.52 ^{a}	3.66±0.57 ^{a}	3.79±0.49 ^{a}
BL (g)	14.88±3.00^{a}	17.89±0.80^{a}	21.60±4.15^{b}	22.43±1.47^{b}
BR (g)	14.45±2.44^{a}	15.99±2.89^{a}	23.94±5.12^{b}	24.84±5.85^{b}
BN (g)	0.05±4.36^{a}	0.34±0.06^{b}	0.67±0.10^{c}	0.71±0.05^{c}

LA: Leaf area**; DC:** diameter at the collar**; BL**: Biomass of leave; **BR**: Biomass of root; **BN**: Biomass of nodules**; C**: 0% of pyroclastic powder per pot (control), **P10**: 10% of pyroclastic powder per pot, **P20**: 20% of pyroclastic powder per pot, **P30**: 30% of pyroclastic powder per pot.

Means with different letters are considered significantly different at $p \leq .05$

3.1.6. Stages of plant development

Throughout the flowering phase, the dates of 1st flowering, 50% flowering, and 100% flowering of *Phaseolus vulgaris* were noted. It appears that all the soils treated with the pyroclastic powder started their 1st flowering, 50% and 100% flowering earlier than the plants in the control (Table 3).

Table 3: Influence of the dose of pyroclastic powder on the flowering dates of *Phaseolus vulgaris*

Treatments	1st flowering	50% flowering	100% flowering
	----------*Days after sowing*---------		
C	36	41	49
P10	34	40	48
P20	34	38	41
P30	34	39	41

C: 0% of pyroclastic powder per pot (control), **P10**: 10% of pyroclastic powder per pot, **P20**: 20% of pyroclastic powder per pot, **P30**: 30% of pyroclastic powder per pot.

Means with different letters are considered significantly different at $p \leq 0.05$

3.1.5. Seed yield

The seed yield of the common bean varied significantly ($p<.05$) depending on the treatment (Table 4). The highest yield was obtained with the P30 treatment (454.77 ± 0.32 kg/ha) while the control had the lowest yield (107.50 ± 0.41 kg/ha). Seeds yield from the treated pot using 30% pyroclastic powder is 4.2 times greater than that from the control. These results relative to seed yield are lower than those reported by [29] on the determination of the optimal mineral fertilizer (NPK) for common bean growth which reported that the average seed yield was 626.17 Kg/ha.

3.1.6. Effects of pyroclastic powder on the absorption of atmospheric nitrogen

The amount of Nitrogen uptake by common bean nodules varied significantly ($p <.05$) depending on the concentration of pyroclastic powder used (Table 4). The amount of this nitrogen varied from 4.76 ± 4.36 kg/ha for the control to 69.27 ± 7.00 kg/ha for P30 treatment. The amount of atmospheric nitrogen fixed from the P30 treatment was 14.55 times greater than that from the control.

Table 4: Effect of pyroclastic powder on common bean yield

Treatments	C	P10	P20	P30
Yield (kg/ha)	107.5±0.41^{a}	160.83±0.39^{b}	359.33±0.53^{c}	454.77±0.32^{d}

NU (kg/ha)	4.76±4.36^{a}	32.06±5.74^{b}	64.13±9.78^{c}	69.27±7.00^{c}

C: 0% of pyroclastic powder per pot (control), **P10:** 10% of pyroclastic powder per pot, **P20**: 20% of pyroclastic powder per pot, **P30**: 30% of pyroclastic powder per pot.
Means with different letters are considered significantly different at p ≤ 0.05

3.1.4. Effects of levels of pyroclastic powder on seeds quality

The seed quality (weight; protein, lipid, carbohydrate, calcium, and magnesium contents) varied significantly (p<.05) depending on the content of pyroclastic powder used. Globally, pyroclastic powder improves the nutritional values of common bean seeds compared to the Control (Table 5).
The weight of seeds from treated pots using 20% (P20 treatment) and 30% (P30 treatment) pyroclastic powder is 1.7 times greater than that of Control. The treatment with 30% pyroclastic powder increased the seed's protein content up to 16% compared to seeds of the control (C).
The highest calcium content is found in the P30 treatment; this is also the case of calcium content which increased up to 59% compared to the Control.

Table 5: **Effect of the content of pyroclastic powder on the seed's nutritional values**

Treatments	**C**	**P10**	**P20**	**P30**
Weight (g)	0.47±0.08^{a}	0.57±0.05^{a}	0.78±0.02^{b}	0.78±0.10^{b}
Proteins (mg/100g)	15.75±0.33^{a}	17.68±0.01^{b}	17.84±0.15^{b}	18.21±0.98^{c}
Carbohydrate (mg/100g)	68.92±0.33^{a}	66.32±0.09^{a}	64.67±0.44^{a}	64.78±0.58^{a}
Lipids (mg/100g)	1.02±0.02^{a}	1.31±0.03^{a}	1.98±0.02^{a}	1.28±0.70^{a}
Calcium (mg/100g)	152.48±2.77^{a}	181.27±11.53^{b}	211.45±14.08^{c}	243.05±19.93^{d}
Magnesium (mg/100g)	51.23±0.23^{b}	53.45±2.58^{b}	41.25±2.78a^{b}	26.25±5.78^{a}

C: 0% of pyroclastic powder per pot (control), **P10**: 10% of pyroclastic powder per pot, **P20**: 20% of pyroclastic powder per pot, **P30**: 30% of pyroclastic powder per pot.

3.1.5. Correlation between parameters

There is a positive correlation between some parameters (p<.05). Yield is positively influenced by the number of leaves and the leaf area (Table 6). When the number of leaves and the leaf area is high, the biomass of nodules is large. These two parameters positively influenced the protein and calcium content.

Table 6: Correlation between parameters

Parameters	**PH**	**NL**	**DR**	**LA**	**BL**	**BR**	**BN**	**Seed yield**	**Proteins**	**Calcium**
PH	1									
NL	0.04	1								
DR	-0.23	0.72	1							
LA	0.10	0.94	0.62	1						
BL	0.18	0.86	0.86	0.77	1					
BR	0.01	0.29	0.02	0.35	0.04	1				
BN	0.05	0.78	0.62	0.84	0.72	0.16	1			
Seed yield	0.01	0.97	0.66	0.92	0.81	0.21	0.82	1		
Proteins	0.03	0.75	0.43	0.81	0.64	0.20	0.66	0.75	1	
Calcium	0.34	0.77	0.55	0.82	0.76	0.20	0.82	0.81	0.66	1

HP: Height of Plants; **NL**: Number of leaves per plant; **DR**: Diameter of root; **LA**: leaf area; **BL**: Biomass of leave; **BR**: Biomass of root; **BN**: Biomass of nodule;

3.2. Effects of the application period of pyroclastic powder on common bean growth and development

The test was carried out simultaneously with the first (effect of the dose of pyroclastic powder on common beans). The concentration of 20% of pyroclastic powder was chosen to test the best time to add the powder, relying on the literature where certain authors showed that the concentration of 20% of pyroclastics was better [26].

3.2.1. Plants Height

The analysis of variance carried out on the results of figure 5 showed that there is a significant difference ($p<.05$) between the average height of the common bean plants at 70 DAS depending on treatments. Indeed, treatments at the sowing stage (SP20) have an average height (24.31±1.88 cm) greater than that of the growing (GP20) stage (22.71±1.00 cm), and the flowering stage (FP20) (20.63±0.99 cm). The control displays the lowest values (15.68±1.18 cm). These results are identical to those of Yaya [11] who reveals that a supply of vivianite powder at the sowing stage is appropriate for the height growth of common bean plants.

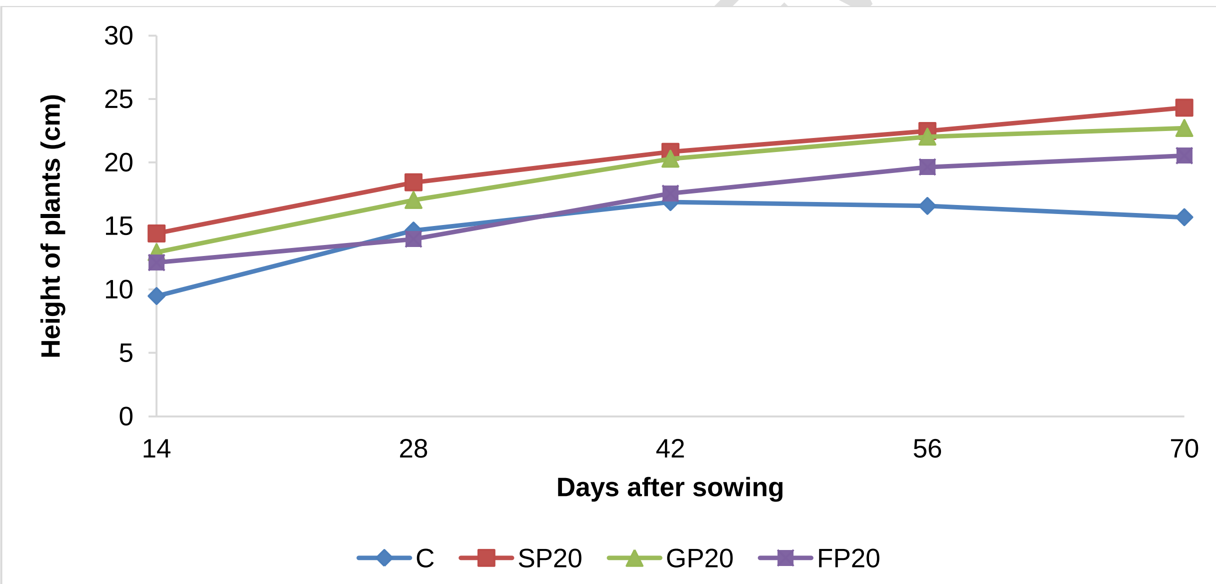

Figure 5: Evolution of the height of the plants according to the period of amendment

C: 0% of pyroclastic powder (control), S**P20**: 20% of pyroclastic powder at the Sowing time, **GP20**: 20% of pyroclastic powder at the Growing time, **FP20**: 30% of pyroclastic powder at the Flowering time.

3.2.2. Number of leaves

At 70 DAS, treatments at the flowering stage (FP20) showed the highest average number of leaves, followed by the plants amended at the growing stage (GP20), and the sowing stage (SP20); the control also displays the lowest values. The average number of leaves are respectively 6.87±1.38, 6.10±1.67, 4.63±1.22 and 2.67±1.15) for FP20, GP20, SP20, and C. However, between the 14^{th} DAS and the 42^{th} DAS, the SP20 treatment recorded the highest mean number of leaves (Figure 6).

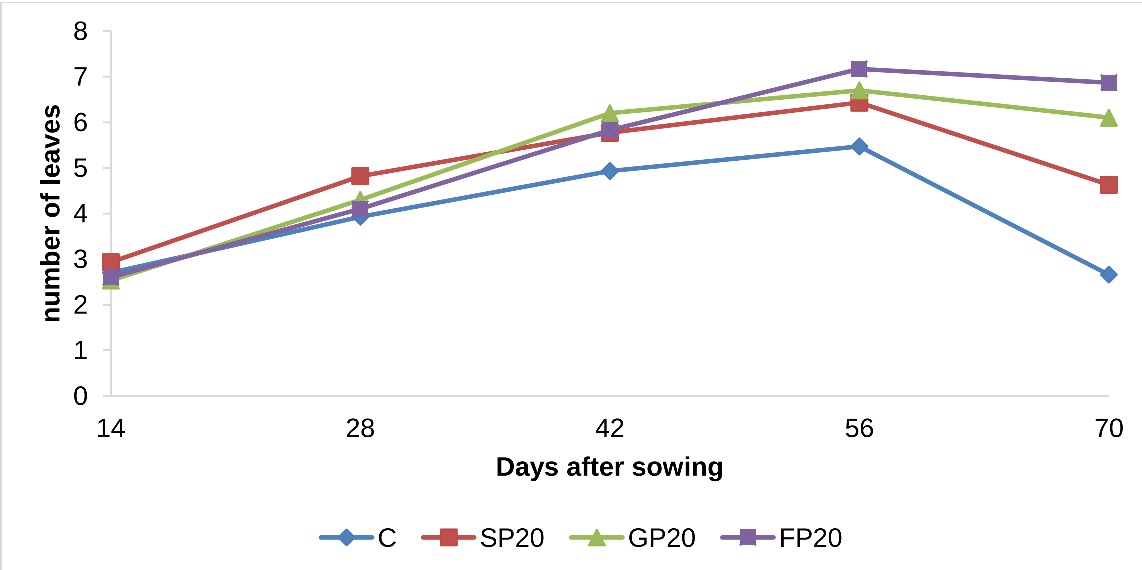

Figure 6: Evolution of the number of leaves according to the treatment

C: 0% of pyroclastic powder (control), S**P20**: 20% of pyroclastic powder at the Sowing time, **GP20**: 20% of pyroclastic powder at the Growing time, **FP20**: 30% of pyroclastic powder at the Flowering time.

3.2.3. Leaf area

Plant leaf area measured differed significantly ($p<.05$) between treatments (Table 7). Indeed, on the SP20, the leaf area is higher (42.70 ± 0.37 cm^2) compared to the Control (32.81 ± 0.60 cm^2). The LP20 and FP20 plants showed a leaf area of 37.39 ± 0.04 cm^2 and 19.81 ± 0.60 cm^2 respectively. Basaltic pyroclastic, by modifying the pH of the soil [12, 26] could have favored the absorption of nutrients by the plants [28] and thus influenced their growth, development, and leaf area at the sowing stage.

3.2.4. Root diameter

The analysis of the variance of data showed that there is no significant difference between all treatments ($p>.05$). However, the SP20 treatment presented the highest diameter at the collar (Table 7).

Table 7: Effect of Pyroclastic powder application time on growth parameters of *P. vulgaris*

Treatments	C	SP20	GP20	FP20
LA (cm^2)	33.79±1.12^{a}	42.70±0.37^{c}	37.39±0.04^{b}	32.81±0.60^{a}
DR (cm)	3.45±0.58^{a}	3.66±0.48^{a}	3.32±0.66^{a}	3.34±0.45^{a}

LA: leaf area; **DR**: Diameter of root; **SP20**: 20 % of pyroclastic powder at Sowing time; **GP20**: 20 % of pyroclastic powder at seedling emergence time; **FP20**: 20 % of pyroclastic powder at flowering time

3.2.5. Biomass of leaves, roots, and nodules

The obtained results showed that there is a significant difference ($p<.05$) between the aerial and root dry biomass of the plants according to the application period of the pyroclastic powder (Table 8). The SP20 treatment showed the highest aerial dry biomass value (25.85±2.44 g) compared to the GP20 treatment (15.51±1.25 g), the FP20 treatment (12.87±1.51g), and the control. (14.88±3.00 g). Furthermore, the highest dry root biomass is also obtained with the SP20 treatment (28.55±2.44 g). Similarly, the dry biomass of nodules is higher in the SP20 treatment (0.58±0.25 g) compared to the GP20 treatment (0.35±0.07 g) and the FP20 treatment (0.25±0.05 g). In addition, the application of pyroclastic powder increased aerial dry matter by 73.72% and root dry matter by 96.91% respectively with the SP20 treatment. Moreover, as on the aerial and root part, the dry biomass of the nodules is higher in the SP20 plants (0.58 ± 0.25 g) compared to the LP20 plants (0.35 ± 0.07 g) and FP20 plants (0.25±0.225g). The results are superior to those of [8]. The increase in the nodular dry biomass as a function of the rock powder application period shows that for good nodule activity.

Table 8: Effect of the RP application period on growth parameters of *Phaseolus vulgaris*

Treatments	C	SP20	GP20	FP20
BL (g)	14.88±3.00[a]	25.85±0.31[b]	15.51±1.25[a]	12.87±1.51[a]
BR (g)	14.45±2.44[a]	28.55±2.44[b]	23.00±5.91[b]	14.50±8.01[a]
BN (g)	0.05±4.36[a]	0.58±0.25[d]	0.35±0.07[c]	0.25±0.05[b]

BL: Biomass of leave; **BR**: Biomass of root; **BN**: Biomass of nodule; **ANF**: Atmospheric nitrogen Fixed; **C:** 0% of pyroclastic powder (control), **SP20**: 20% of pyroclastic powder at the Sowing time, **GP20:** 20% of pyroclastic powder at the Growing time, **FP20:** 30% of pyroclastic powder at the Flowering time.

3.2.6. Date of flowering

It appears from Table 9 that the application period of pyroclastic influences the flowering of common bean plants. An application of 20% of pyroclastic powder at the sowing stage allows the plant to have the 1st flowering 2 days before the Control, the 50% flowering was effective 3 days before the Control, and the 100% flowering was completed 8 days after the control.

Table 9: Effect of the application period on flowering dates of *Phaseolus vulgaris*

Treatments	1st flowering	50% flowering	100% flowering
	----------*Days after sowing*---------		
C	36	41	49
SP20	34	38	41
GP20	35	40	44
FP20	36	41	42

C: 0% of pyroclastic powder (control), S**P20**: 20% of pyroclastic powder at the Sowing time, **GP20**: 20% of pyroclastic powder at the Growing time, **FP20**: 30% of pyroclastic powder at the Flowering time.

3.2.7. Effects of the application period of pyroclastic powder on common bean production

Studied production parameters include seed yield and biological yield (Nitrogen Uptake). These production parameters varied significantly ($p<.05$) depending on the application period of the pyroclastic powder (Table 10). The seed yield of common bean varied from 107.50 ± 0.41 kg/ha for the Control to 306.87 ± 0.27 kg/ha for treatment at the sowing stage. Seed yield from treatment at the sowing stage was 1.78 times greater than that from treatments at the flowering stage.

The content of atmospheric nitrogen fixed by treated plants at the sowing stage was 2.32 times greater than that at the flowering stage. These results suggest that early application of pyroclastic powder improves the potential ability of nodules to fix atmospheric nitrogen and therefore improve the soil's nitrogen fertility. The analysis of variance reveals that the period of pyroclastic application significantly influences ($p<0.05$) the grain yield of common bean (Table 10).

It was reported in this study that the amount of nitrogen fixed from the treated plants by 30% of pyroclastic powder was 14.55 times greater than that of the control. The improvement in soil properties favored the development and activity of nodules and led to the better fixation of nitrogen [30].

Table 10: Effects of date of application on common bean production

Treatments	**C**	**SP20**	**GP20**	**FP20**
Seed yield (kg/ha)	107.50±0.41^{a}	306.87±0.27^{d}	210.23±0.25^{c}	172.13±0.37^{b}
NU (Kg/ha)	4.76±4.36^{a}	55.86±2.88^{d}	33.65±6.48^{c}	24.13±4.79^{b}

C: 0% of pyroclastic powder (control), S**P20**: 20% of pyroclastic powder at the Sowing time, **GP20**: 20% of pyroclastic powder at the Growing time, **FP20**: 30% of pyroclastic powder at the Flowering time. **NU**: Nitrogen Uptake.

3.2.8. Effect of the application period of pyroclastic powder on seeds quality

Globally, the statistical analysis indicated that the seed quality (weight; protein, carbohydrate, lipid, calcium, and magnesium content) varied significantly ($p<.05$) depending on the period of application of the pyroclastic powder (Table 11). The application of 20% pyroclastic powder at the sowing stage increased the seed weight by 63% compared to the control. In the present study, the seed's weight varied from 0.47±0.08 g to 0.82 ± 0.06 g. Application of pyroclastic powder at the germination stage improves common bean seed quality.

Seed protein content ranged from 15.75 ± 0.33 g for the Control to 19.78 ± 0.89 g for treatment at the sowing stage (Table 11). The seed protein content of the treated plant at the sowing stage was 1.05 and 1.11 times higher than that of treatments at the germination and flowering stages.

The application of 20% pyroclastic powder at the sowing stage increased the calcium content of seeds by 63% compared to the control (Table 11).

Magnesium content is also influenced by the application period of the pyroclastic powder (Table 11). A reduction of -54.23 % of the magnesium content is observed at the sowing stage when compared to the Control. This decrease is about -31.19 % for treatments at the growing stage. This concentration increases slightly in the treatments at the flowering stage but remains lower than the Control by -11.28 %. The beneficial effect of pyroclastic powder relative to the nutritional value of common bean seeds would be due to the increase of mineral elements in the soil solution after the weathering of the basalt pyroclastic [12,26]. Indeed, calcium is an immobile element in the plant. Its increase in plant organs is mainly due to an increase in its absorption by the roots [31, 32]. In the current study seed's weight varied from 0.47±0.08 g to 0.82 ± 0.06 g, these values are higher than the data reported by [33] who noted that the average weight of common bean seed was 0.42 g.

Table 11: Effect of the application period of pyroclastic powder on the seed's physicochemical properties

Treatments	C	SP20	GP20	FP20
Weight (g)	0.47±0.08^{a}	0.80±0.02^{b}	0.82±0.06^{b}	0.54±0.08^{a}
Protein (mg/100g)	15.75±0.33^{a}	19.78±0.89^{c}	18.88±1.96^{b}	17.84±1.43^{b}
Carbohydrate (mg/100g)	68.92±0.33^{a}	65.58±3.29^{a}	5.41±2.02^{a}	62.96±1.15^{a}
Lipids (mg/100g)	1.02±0.02^{a}	1.18±0.02^{a}	1.06±0.50^{a}	1.04±0.28^{a}
Calcium (mg/100g)	152.48±2.77^{a}	248.26±1516^{d}	209.53±4.25^{c}	198.75±20.42^{b}
Magnesium (mg/100g)	51.23±0.23^{c}	23.45±2.45^{a}	35.25±4.65^{b}	45.45±4.45^{c}

C: 0% of pyroclastic powder (control), **SP20**: 20% of pyroclastic powder at the Sowing time, **GP20**: 20% of pyroclastic powder at the Growing time, **FP20**: 30% of pyroclastic powder at the Flowering time.

3.2.9. Correlation between parameters

Table 12 shows the correlation that exists between the studied parameters; it appears that there is a positive correlation between certain parameters at the threshold of 5%. Indeed, the yield is strongly correlated to the leaf area, the number of leaves, and the dry biomass. Similarly, the protein content is positively and significantly correlated with these same parameters.

Table 12: Correlation between parameters

Parameters	PH	NL	DR	LA	BL	BR	BN	Seed yield	Proteins	Calcium
PH	1									
NL	-0.06	1								
DR	-0.07	-0.01	1							
LA	0.31	-0.43	0.22	1						
BL	0.27	0.22	0.02	0.22	1					
BR	0.31	0.29	0.21	0.29	0.43	1				
BN	0.27	0.69	0.17	0.69	0.72	0.57	1			
Seed yield	0.39	0.47	0.40	0.47	0.39	0.62	0.82	1		
Proteins	0.10	0.75	0.10	0.75	0.21	0.22	0.63	0.55	1	
Calcium	0.30	0.27	0.27	0.27	-0.1	0.52	0.30	0.62	0.22	1

HP: Height of Plants; **NL**: Number of leaves per plant; **DR**: Diameter of root; **LA**: leaf area; **BL**: Biomass of leave; **BR**: Biomass of root; **BN**: Biomass of nodule

Conclusion

Soils from the Bini-Dang locality (Ngaoundere, Cameroon) are acidic and display limiting factors for better common bean productivity. The application of pyroclastic powder significantly (p <.05) improves the growth, seed yield, and seed nutritional values of *P. Vulgaris*. However, an application of 30% pyroclastic powder at the sowing stage appears to be a good concentration and a good period to obtain an optimal yield. The Pyroclastic powder can therefore be recommended as a petrofertilizer to farmers in Ngaoundere (Cameroon).

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