International Research Journal of Earth Sciences ISSN 2321–2527
Vol. **3(4),** 18-26, April **(2015)** *Int. Res.J. Earth Sci.*

Assessment of the Fertilizing effect of Vivianite on the Growth and yield of the Bean *''phaseolus vulgaris''* on Oxisoils from Ngaoundere (Central North Cameroon)

Yaya Fodoué[1,2], Nguetnkam J.P.[2]*, Tchameni R.[2], Basga S.D.[3] and Penaye J.[1]
[1]Research Center of Geology and Mining P.O Box 333, Garoua, CAMEROON
[2]Department of Earth Sciences, Faculty of Science, University of Ngaoundere, P.O. Box 454 Ngaoundere, CAMEROON
[3]Institute of Agricultural Research for Development (IRAD) P.O. Box 12 Yagoua, CAMEROON

Available online at: www.isca.in, www.isca.me
Received 6th March 2015, revised 5th April 2015, accepted 22th April 2015

Abstract

The use of phosphate rocks has become agronomical and economically more beneficial compared to chemical fertilizers. In this study, the fertilizing effect of vivianite (a phosphorus rich mineral) from Hangloa on the growth and yield of the bean plant ''Phaseolus vulgaris'' on oxisoils from Ngaoundere is assessed. To this end, field investigations along with geochemical analysis, tests solubility and pot experiments have been carried out. Vivianite is located in the Hangloa lacustrine basin, situated at 25 km NW of the Ngaoundere town. Three different types of vivianite were identified: rosette, disk and vivianite in fragments within argillites. The solubility test was carried out by using the acid formic method. For the pot experiments, the design consists in a randomized complete block and constituted of two series of four treatments each: the control (T_0) without any addition of vivianite, the control with 20g of vivianite in the hole of sowing (T_1), the control with 20g of vivianite at the germination stage (T_2) and the control with 20g of vivianite at the flowering stage (T_3). Each treatment was replicated ten times. All the treatments were irrigated with 250 ml of water once every 2 days during the growing stage. The growth and yield parameters were measured after each three days. 12320 measures of growth components and 30721 measures of yield components were made. The geochemical analysis revealed that the vivianite of Hangloa has a high phosphorus content (9.17 %.) which can be easily dissolved in soil as revealed by the solubility test. A total dissolution rate of 53.48% was obtained at the end of experiment. The application of vivianite has a positive effect on the growth and the yield of the bean plant in the oxisoils from Ngaoundere: an increase of length and ramifications of stem, densification and extension of leaves, development of root system along with an increase of bean yield is observed in amended soils. The best periods for amendment of oxisoil with vivianite are the germination and flowering stages. The overall results indicate that vivianite can be used to enhance the bean crop yield in oxisoils from Ngaoundere and therefore is a good alternative local agromineral to chemical fertilizers commonly used.

Keywords: Ngaoundere, Hangloa, vivianite, *phaseolus vulgaris*, oxisoils, amendment.

Introduction

To ensure food security in developing countries, the valorization of natural phosphate is needed in order to improve agricultural productivity and increase revenues. In this context, new technologies applied to soils should be developed, implemented, tested and transferred to farmers[1,2]. Currently mineral fertilizers are essential including phosphorus (P), which allows increasing crop yields. Thus the water-soluble phosphate fertilizers such as superphosphates manufactured are generally recommended to increase agricultural yield[3-5]. Those fertilizers are imported, but still very expensive for poor farmers of most developing countries, and as consequence they are often used in limited quantities. Agricultural production in those countries requires P to improve soil P status in view to increase crop yield, to avoid soil degradation and infertility[6, 7]. Thus, in several countries such as Morocco, China, the United States, Denmark, Brazil etc., the use of phosphate rocks (PR) from geological formations has became an agronomical and economically attractive alternative compared to chemical fertilizers. These PR have the potential to compensate the low phosphorus content of tropical and subtropical soils[1]. Like many developing countries, the direct use of local raw materials such as PR not only contributes to the substitution of imported products but it also improves the fertility of depleted soils. Vivianite is very rich in iron and phosphorus ($Fe_3(PO_4)_2 8H_2O$)[8]. In Cameroon, it outcrops in the small lake basins of Hangloa in Adamawa more specifically in the NW of Ngaoundere (figure-1). Vivianite is of little interest in this sub region because it is not valued, yet the majority of inputs (phosphorus, calcium, magnesium, iron, etc.) necessary for good plant growth is from geological materials, except nitrogen that can be provided by sources such as crop residues and other organic products[1]. These geological materials which have the advantage of locally available and inexpensive contribute significantly in some countries to provide the essential elements for high-quality agriculture and restore at the same time the balance of the soil[1]. The developing countries and therefore Cameroon should face major challenges in valorizing mineral rich in phosphorus to achieve sustainable food security. The valorization of locally available resources could solve the problem of high cost, adverse effects of fertilizers and help increase crop yield per square meter of cultivated land. Moreover, it was shown that the substantial contribution of phosphorus is needed for optimal growth and production of suitable plants. In order to assess the fertilizing effect of vivianite, geochemical analysis was made to ascertain the elemental composition of vivianite and afterwards, a dissolution phosphorus test was realized on vivianite and finally an experimental study was undertaken by measuring the parameters of growth and yielding of beans when vivianite is added to the soils at different evolution stages of the bean.

Location and Geological Setting: The vivianite lake basin of Hangloa is located at the Center North Cameroon, 25km North-West of Ngaoundere chief town of the Adamaoua region (figure-1). Topographically, it is a depression of about 2km² and surrounding by Panafrican granitic rocks and more and less altered Cenozoic basaltic lavas. In this depression, a lacustrine sedimentary sequence is made up essentially of clays, coarse sediments and of various sizes of vivianite crystals. Three types of vivianite crystals have been identified in this basin: i. - Vivianite in the form of disk. They outcrop as shape ellipsoid flattened blocks and display a diameter varying between 20 cm and more than one meter. ii. - Vivianite in form of fragments within argillites. iii. - Vivianite in rosette, which appears as a collection of crystals that radiate from a center.

These different forms of vivianite encounter oxidation on contact with air and become very dark in color which is an indication of the beginning of their alteration or degradation.

Material and Methods

Materials: Materials used in the present study are vivianite, oxisoils and a plant material (bean: *Phaseolus vulgaris).*

Vivianite: Two samples of vivianite and one vivianite within argillite were subject to geochemical analyses (figure-2): the sample S1 is the core of the vivianite in rosette shaped; the sample S2 is collected to the altered border of the vivianite in rosette shaped and the sample S3 is the argillite which contents millimeter crystals of vivianite. The sample S1 was used for pots experiments.

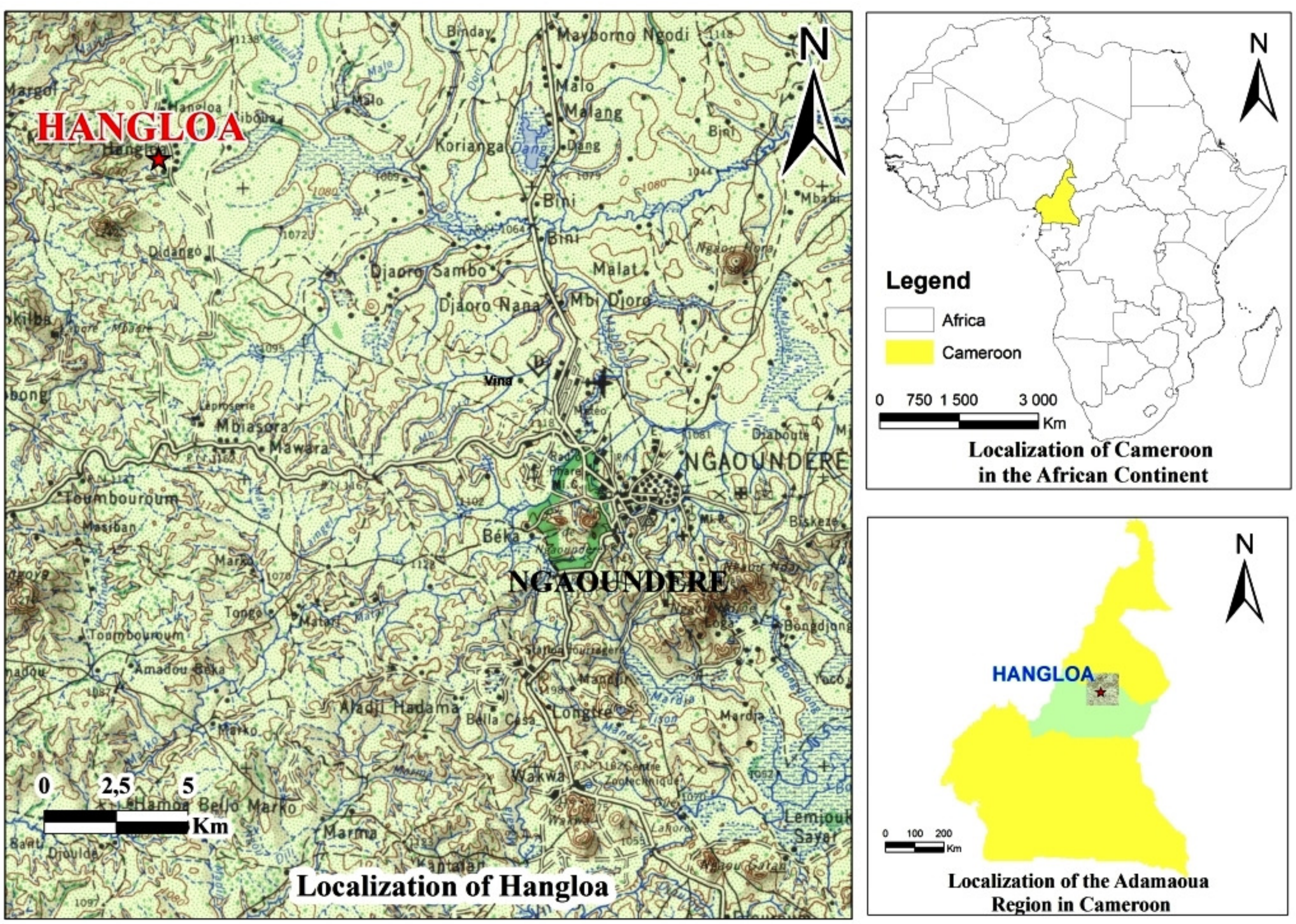

Figure-1
Site location

Figure-2.a
Vivianite in disk

Figure-2.b
Vivianite in rosette

Figure-2.c
Vivianite in rosette

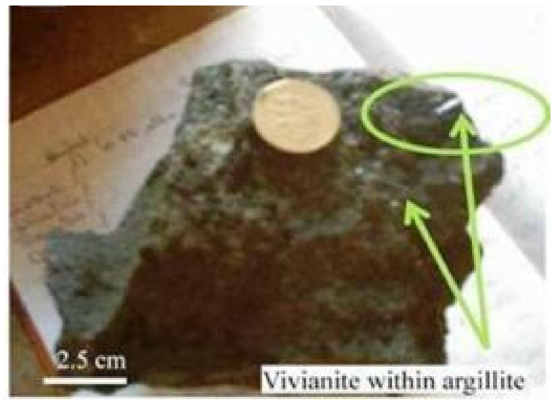

Figure-2.d
Vivianite within argillite

Oxisoils: The oxisoils were collected at different points of the surface horizon (organo mineral horizon: 0-10 cm) at Marza, a locality of Ngaoundere town (figure-1). Then after air dried, a composite soil sample was obtained by mixing all the soil samples and quartered. 2 kg of composite soil were put in pot containers.

Plant material: Common bean *Phaseolus vulgaris* was used as plant test. This variety was chosen because of its need for phosphorus and its alimentary importance in the sub-region. It also adapts easily to the conditions of the experimental environment. Three (03) seeds were planted in 3 cm depth of soil. Pots were irrigated immediately after sowing.

Methods: Geochemical Analysis: Geochemical composition was determined by X-ray Fluorescence dispersion wavelength (wavelength-dispersive X-Ray Spectrometers) on the three types of vivianite mentioned above (S1, S2 and S3). This qualitative and quantitative method is non-destructive and enables to determine the elemental composition of the material.

Dissolution Test of phosphorus: The dissolution test has been carried out on sample S1at Ngaoundere University's laboratory of National School of agro industrial Sciences (ENSAI). To this end, a kinetic experiment was implemented and the obtained solution was extracted at six different times: 4h, 4h20, 4h40, 5h, 5h20 and 5h40. The extraction method adopted for the dissolution test of phosphorus is that of Truong et al.[9]. The solution used in this experiment is a concentrated formic acid (2%). The advantage of this method is that it removes a great part of phosphorus in the natural phosphate. After extraction, 20 ml of each solution sequentially obtained is put into control tubes for the determination of orthophosphate ion (PO_4^{3-}).

Pots experiment: A pot experiment was carried out in a familial greenhouse at Ngaoundere town. 2 kg of a composite oxisoil sample was put in pot containers. The experimental design is a duplicated randomized block design constituted by four treatments each one: the control (T_0) without any addition of vivianite, the control with 20g of vivianite in the hole of sowing (T_1), the control with 20g of vivianite at the germination stage (T_2) and the control with 20g of vivianite at the flowering stage (T_3). Each treatment was replicated ten times in every serie and irrigated 3 times before the sowing. The treatments were repeated twice in order to validate the obtained results.

Experimental monitoring and data analysis: The experimental monitoring consisted to measure growth parameters (observation of rising date, stem length, leaf width, number of leaves, length of the main veins, number of branching roots and root length). Leaf area was determined using the non-destructive method[10]:

LA= 11.98+ 0.06 x (LL x LW)

Yield parameters (flowering, pods number, average weight per pods, grain number and grain mass) were also measured. This monitoring took place over a period of 82 days. All the treatments were irrigated with 250 ml of water once every 2 days during the growing stage. Measurements were made every three days. Data analyses and graphs were done with excel program (2007) and XLSTAT software. Pearson's correlation was used in order to determine relationships between growth components and yield parameters.

Results and Discussion

Geochemical composition of vivianite: The results of geochemical analyses, presented in table-1, revealed that vivianite is constituted mainly of silica, alumina, iron and phosphorus. The content of alkali and alkali elements is less than 1 and titanium amounts vary between 0.83 and 2.3%.

Table-1
Representative analyses of vivianite samples

Samples	S1	S2	S3
sample characteristics	core of vivianite crystal	alterated border of the vivianite crystal	vivianite within argillite
Oxides (%)			
SiO_2	9.67	59.35	51.06
TiO_2	0.83	1.91	2.37
Al_2O_3	7.72	12.89	14.61
Fe_2O_{3T}	68.72	12.75	14.44
MnO	0.18	0.03	0.12
MgO	0.12	0.1	0.35
CaO	0.09	0.1	0.83
Na_2O	-	-	0.05
K_2O	0.05	0.14	0.21
P_2O_5	9.17	3.09	1.11
SO3	0.13	0.51	0.67
LOI	3.2	8.96	13.87
Sum	99,88	99.83	99.69
Trace elements (ppm)			
Ba	-	-	626.962
Cu	-	79.884	79.884
Nb	-	79.889	79.889
Ni	157.168	78.584	157.168
Sr	253.677	338.677	507.354
Tb	-	90.853	90.856
Zn	370.15	471.504	444.18
Zr	335.682	402.819	402.819

It appears in figure-3 that sample S1 displays highest content in Fe_2O_3 (68.72%) and P_2O_5 (9.17%) and lowest content in SiO_2 (9.67%) and Al_2O_3 (7.72%), whereas samples S2 and S3 display highest content in SiO_2 (51.06 – 59.35%), average in Fe_2O_3 and Al_2O_3 (12 – 14%) and lowest content in P_2O_5 (1.11 – 3.09%).

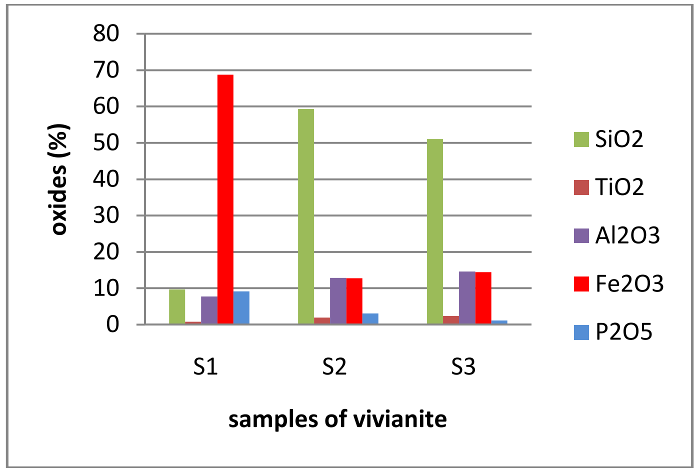

Figure-3
Major oxides content in the analyzed vivianite samples

Dissolution of phosphorus: The result of the dissolution test revealed that all the extracted solution turned in blue which is an indication of the presence of orthophosphate and implies that the phosphorus contained in vivianite is dissolved. The dissolution rate decreases with time; it is higher (20%) at the first extraction (4h) and very low (1.69%) at the end of the experiment (5h40) (figure-4). The total dissolution rate obtained at the end of experiment is 53.48%.

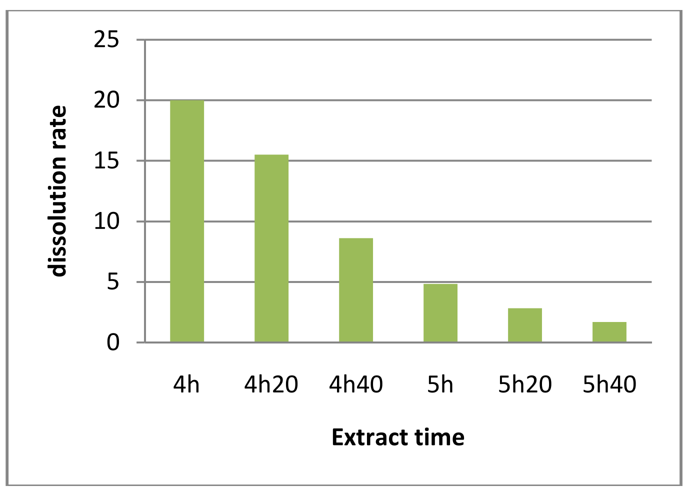

Figure-4
Dissolution rate of vivianite with time

Agronomic effectiveness of vivianite on the growth and yield of beans: Growth parameters: The table-2 shows the variation of growth parameters during the growing stage.

Germination: Germination of beans during the experiment did not occur at the same time. The germination started 5 days after sowing (DAS) in the control treatment (T_0) and 8 DAS in the soil where vivianite was incubated before sowing (T_1). So a delay of 3 days is observed in treatment T_1. Therefore it can be deduce that the addition of vivianite before sowing does not induce a rapid growth of bean.

Length stem: 3040 measurements were made. A gradual increase of length stem is observed up to the end of the experiment in all treatments. The maximal mean values of stem length varied between 18.6 and 26.135 cm (figure-5). The lowest value is observed in T_0 and the highest in T_1 and T_2 (figure-5; table-2). So it appears that an amendment with vivianite induces stem elongation.

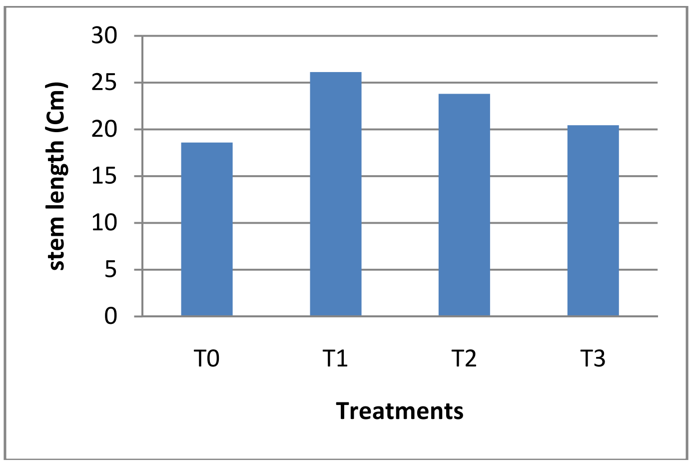

Figure-5
Stem length in different treatments

Number of leaves per plant (NL): The variation of leaves per plant in different treatments during the experiment is presented in figure-6. The number of leaves gradually increases and begins to decrease at 51 DAS in T_0 and 57 DAS in the fertilized treatments with vivianite up to the end of experiment.

The defoliation is more pronounced in the control soil. In this soil the maximum number of leaves per plant in serie A was 8 and 11 in serie B. which gave an average of 9.5 leaves per plant. In T_1 14 leaves were observed in serie A and 15 leaves in serie B with an average of 14.5 leaves. On the soil where vivianite was added at the germination stage (T_2) there are 18 leaves in A serie and 16 in B serie with an average of 17 leaves. In the T_3 treatment the maximum number of leaves per plant in both series is 13. These results show that plants from fertilized soils have more leaves compared to that of the reference. On these fertilized soils the plants of T_2 recorded more leaves than others. The contribution of vivianite as fertilizer allows the beans to produce more leaves per plant.

Leaf width (LW): The obtained result from leaf width measures reveals an increase of the width in all treatments up to the end of monitoring. Control soil (T_0) gave a maximum width of 8.25 cm while in T_1 and T_2 treatments a maximum width of 9.9 cm is observed (table-2). The treatment T_3 displays the lowest value with leaves with maximum width value of 7.48 cm, so leaves in T_1 and T_2 treatments are more developed than that of the control and T_3 treatment. Therefore it can deduce that vivianite has significantly influence the leaf width in T_1 and T_2 than in T_3 treatment.

Leaf Length (LL) and leaf area (LA): 3040 measures of the leaf length have been done. A gradual and continuously increases is observed in all treatments during the experimental period. The maximal leaf length obtained in the control soil (T_0) is 9.26 cm in A serie and 9.41 cm in B serie which gave an average of 9.34 cm. In T_1 treatment the values of leaf length in both series are respectively 8.92 cm and 8.98 cm for an average of 8.95 cm (table-2). In T_2 treatment 9.81 cm of leaf length is recorded in A serie and 9.89 cm in B serie with a mean of 9.85 cm. In the T_3 treatment where vivianite was added at the flowering stage, A and B series gave respectively 9.29 cm and 9.19 cm of leaf length with an average of 9.24 cm. These results show that in general treatments with vivianite display higher leaf length that that of the control (T_0) except for T_3 treatment. This implies that adding vivianite at the sowing and the germination stages induces leaf elongation. Since the LA is deduced from leaf length and leaf width it appears that the highest values of leaf area are observed in T_1 and T_2 treatments while T_0 and T_3 display similar values of leaf area.

Roots ramification: The number of roots obtained after monitoring is 7 in the treatment T_0 while T_1 and T_2 treatments display an average of 8 and 9 roots respectively. Treatment T_3 has the highest number of roots (10 roots). So the number of roots in soils amended with vivianite is higher than that of the control soil. The addition of vivianite at the flowering stage appears to be the best period since it can induce the development and the increase of the number of branching roots. But the roots are longer in the control treatment than in the soils amended with vivianite.

Yield parameters: Data on charge of yield parameters are gathered in table-3.

Flowering and bean grains output: The period at which beans come into bloom varies with treatments. The blooming period occurs thirty four (34) days after sowing (DAS) in $T_1$and T_3 treatment and 36 DAS in T_2 and T_0. A maximum of 8 flowers were recorded in T_0 and T_2 while in T_1 and T_3 11 and 9 flowers were obtained (table-3). Soils amended with vivianite display higher number of flowers than the control. All these flowers have produced pods; however all pods have not reached maturity (figure-7). The number of flowers obtained is higher in T_1 and T_3 treatments. Application of vivianite before sowing increase flowers production per plant.

Table-2
The average value of growth parameters

	Length stem		Number of leaves		Leaf wide		Leaf length		Number of roots		Leaf area	Length roots
Treatments / Range	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**average**	**average**
T_0	19.50	17.70	8.00	11.00	8.20	8.30	9.26	9.41	7.50	7.00	16.60	26.30
T_1	25.47	26.80	14.00	15.00	10.60	9.20	8.92	8.98	8.57	8.25	17.30	18.70
T_2	24.30	23.70	18.00	16.00	10.30	10.30	9.81	9.89	9.80	7.50	18.07	17.90
T_3	19.90	21.00	13.00	13.00	7.36	7.60	9.20	9.18	10.20	8.33	16.10	22.12

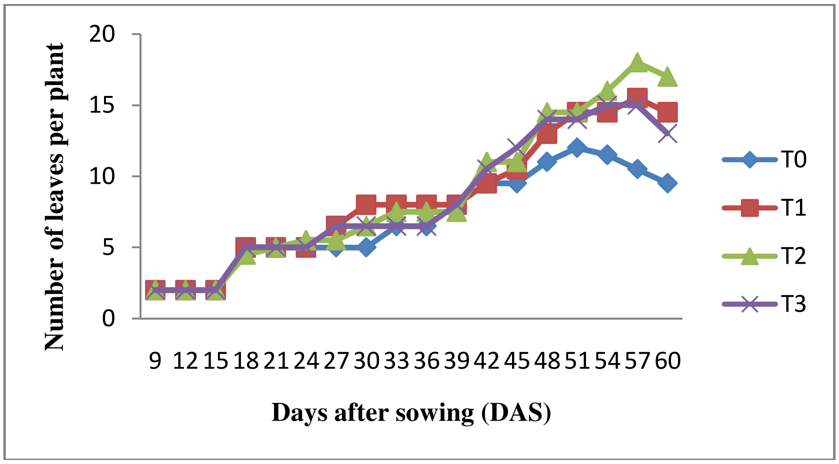

Figure-6
Number of leaves per plant

Table-3
Variation of yield parameters

Treatments	Number of flowers	Pods per plant	Number of maturity pods	Weigth per pods	Number of grain	mass per grain
T_0	8	8	6	1.40	2.33	0.33
T_1	11	11	7	1.20	2.30	0.295
T_2	8	8	6	1.40	2.41	0.335
T_3	9	9	6	1.50	2.90	0.335

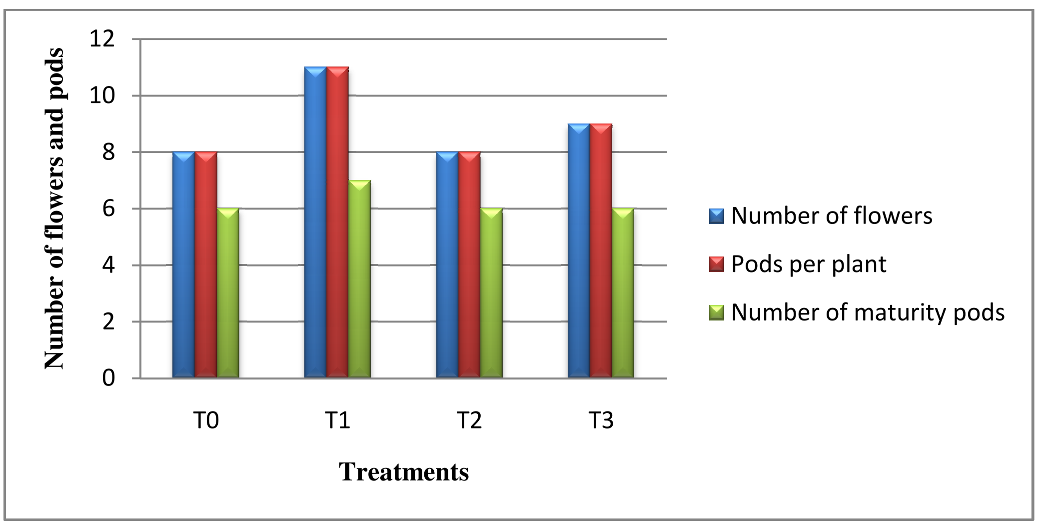

Figure-7
Average number of flowers and beans in different treatments

Number of matured beans pods: Figure-7 shows that all the flowers gave beans grains. However the number of beans at maturity is less than the number of beans out. Plants from T_0, T_2 and T_3 Treatments have recorded the same number of matured pods (6) while T_1 displays the highest number of pods (7 pods). This indicates that the addition of vivianite during the sowing stage improves the production of pods.

Pods Weight: The weight of beans pods obtained in different treatments ranges from 1.1g to 1.5g. Treatment T_0 resulted on the average mass of beans equal at 1.4g. The weight of the beans pods in the treatment T_1 is 1.2g while it is 1.4g in T_2. In treatment T_3 the average mass of bean is 1.5g (table-3).

Number of grains per pod: The number of grains obtained per pod is similar (2.3) in T_0 and T_1 treatments (table-3). In T_3 this number is slightly higher (2.9) than those of others treatments (table-3). So, vivianite has not influenced the number of grains in T_0 and T_1 treatments; while in T_2 and T_3 treatments the addition of vivianite has positively influenced grain production by pod.

Grain weight: The grain weight in different treatments ranges between 0.295 and 0.335g. Grains from T_0, T_2 and T_3 treatments are similar and display highest weight while those from T_1 display the lowest number (table-3). It appears that T_1 which has a higher number of matured pods recorded a lower grain weight.

Yield per hectare: The maximum number of matured pods in a plant and the maximum number of grains by pods are observed in soils amended with vivianite (table-4). Among the main treatments it appears that the addition of vivianite during seeding provides a number of beans yielding significantly higher than the two other treatments (table-4).

Statistical analyses: Pearson's correlation result is presented in table-5. The Pearson matrix shows significant relationships between NP and NF (0.943), Y and NG (0.841).There is also a significant relationship between LA and LW (0.967). The others correlations are not significant: Y and NP (-0.526), Y and WS (0.592), NG and NP (-0.422), Y and NF (-0.219).

Table-4
Average yield of beans and seeds per hectare

Treatments	Average number of grain/pods	Average weight of grain	Yields Ton/ha
T_0	13.86	0.330	2.744
T_1	16.10	0.295	2.849
T_2	14.46	0.335	2.906
T_3	17.40	0.335	3.497

Discussion: Geochemical composition of vivianite from Hangloa: Vivianite is an oxide of iron and phosphate; its formula is Fe_2^{3+} $(PO_4)_2 8H_2O$ and it crystallizes in the monoclinic system[8]. The high content of silica and alumina of the analyzed samples may be due to contamination by clay materials. The studied vivianite contains some Mn (2.6% MnO), Mg (1.9% MgO), Ca (0.1% SiO_2) implying that there is a substitution of iron by Mn, Mg and Ca[8]. The phosphorus contents in vivianite are much higher than those generally obtained in granites and basalts (P_2O_5<1%) in the region of Ngaoundere[11-13]. The high concentration of phosphorus in the vivianite suggests that this mineral can be used for soil improvement fertility provided that the phosphorus can be released from the crystal lattice and dissolved in the soil as many phosphate rocks and minerals[3,4,6,7]. The variation of oxide contents found in the analyzed samples suggests the mobility capacity of those oxides. Their mobility is induced generally by alteration of the mineral in contact with air and water which promotes the release of some elements or their substitution by other elements.

Table-5
Pearson's matrix showing linear correlation between the beans growth and yield parameters

Parameters	ST	NL	LW	LL	NR	LA	RL	NF	NP	NG	WG	Y
ST	**1**	-	-	-	-	-	-	-	-	-	-	-
NL	0.797	**1**	-	-	-	-	-	-	-	-	-	
LW	**0.824**	0.732	**1**	-	-	-	-	-	-	-	-	-
LL	-0.086	0.416	0.356	**1**	-	-	-	-	-	-	-	-
NR	0.362	0.637	-0.035	-0.001	**1**	-	-	-	-	-	-	-
LA	0.698	0.756	**0.967**	0.581	-0.021	**1**	-	-	-	-	-	-
RL	-0.915	-0.969	-0.765	-0.199	-0.611	-0.726	**1**	-	-	-	-	-
NF	0.670	0.188	0.220	-0.796	0.257	-0.022	-0.419	**1**	-	-	-	-
NP	0.752	0.213	0.457	-0.668	0.013	0.217	-0.445	**0.943**	**1**	-	-	-
NG	0.188	0.170	-0.384	-0.569	**0.806**	-0.481	-0.253	0.570	0.268	**1**	-	-
WG	-0.685	-0.110	-0.426	0.691	0.104	-0.183	0.347	-0.915	-0.993	-0.192	**1**	-
Y	-0.205	0.093	-0.604	-0.162	**0.816**	-0.562	-0.042	0.034	-0.294	**0.841**	0.370	**1**

Values in Bold character are significantly correlated at the level of 0.08%; *NL: Number of Leaves; LW: Leaf width; LA: leaf area; SL: stem length; LL: Leaf length; RL: root length; NR: number of root ramifications; NF: number of flowers; NG: Number of grain; NP: number of pods at maturity; GW: Grain weight; Y: Yield.*

Dissolution of phosphorus in vivianite: The blue color obtained after determination of orthophosphate in the extraction solution of formic acid is indicative of the presence of phosphorus[3,4,14-17]. The phosphate ions react with acidic ammonium molybdate to form a complex phosphor molybdic which displays a blue color after reduction by ascorbic acid. It appears afterwards that formic acid can induce the release of phosphorus contained in the vivianite[1,3,4]. Therefore, the roots of plants (such *Phaseolus vulgaris*) which have the ability to secrete enzymes such as phosphate organic acids (citric acid, formic acid) can then promote the dissolution of phosphorus[17,18,19,20]. Vivianite spread on the soil can increase soil nutrients following the phosphorus organic secretions of enzymes by microorganisms or roots of some plants.

Fertilizing effect of vivianite on the growth and yield of beans on oxisoil from Ngaoundere: Results of growth parameters have revealed that *Phaseolus vulgaris* has shown a good response to the addition of vivianite. However when considering the ratio root / stem. It appears that plants that have not received vivianite show an important RL/SL ratio (table-6). This result is similar to that obtained by[17] who stated that plants respond to the lack of phosphorus by the growing of root / shoot ratio.

Table-6
Ratio Root / Stem

Treatments	T_0	T_1	T_2	T_3
Root length (RL)/Stem Length (SL)	1.413	0.715	0.745	1.081

This author further states that treatments with high root / shoot ratio values have a large phosphorus demand. The results obtained in the present study show that bean have developed more roots in amended soils with vivianite than in the control soil. The consequence is that a more ramification of roots allows the plant to uptake more nutriments and therefore phosphorus. The addition of vivianite does not influence the length of the stem but allows the roots to have more branching.

The effect of the use of vivianite as fertilizer appears clearly at the end of the monitoring: the yield of bean in the soil amended with vivianite is higher than in the control. This result is similar to those of several authors[21,22] which confirm that phosphorus contributes to increase the efficiency of plants and weight of grains. In addition they noted that the addition of fertilizer at planting provides a good yield of plants which is consistent with the results obtained in the present study with T_1 and T_2treatments. There is a relationship between grain weight and the uptake of phosphorus by the plant[17]: heavier are the grains more phosphorous are uptake. This result is consistent with the one obtained in the present study with T_3 treatment which displays heavy grains than other treatments. Thus to obtain a great efficiency in grain weight without considering other factors such as number of grains it is advice to bring vivianite during the flowering stage as suggest by many authors[23.24.25]. This result indicated clearly that the best period to use vivianite as fertilizers correspond at period of intense absorption of plant (flowering).

Overall, the use of vivianite as fertilizer greatly impacts the growth and the yield of bean. This is due to an important phosphorus uptake by plant test. In general, the bean crop has responded positively to the contribution of vivianite by improving the parameters of growth and yield.

Conclusion

This study aimed to assess the fertilizing effect of vivianite on the growth and yield of beans on the oxisoils from Ngaoundere. The work has resulted in the following main results: vivianite from Hangloa contains a very high amount of phosphorus oxide which can be greatly released from its crystal lattice and be dissolved in the soil and be available for plant nutrition. The growth and yield of beans have responded positively to the contribution of vivianite as a source of phosphorus. In fact, an increase of ramifications of stem, densification and extension of leaves, development of root system along with an increase of bean yield is observed in amended soils. The germination and flowering stages are the best periods for amendment of oxisoil with vivianite. The overall results indicate that vivianite from Hangloa located in a sedimentary basin can be used as natural phosphate fertilizer alternative to chemical fertilizers commonly used.

References

1. FAO., Utilisation des phosphates naturels pour une agriculture durable, Bulletin FAO engrais et nutrition végétale., **13**., Rome **(2004)**

2. Amberger A., Environmentally sound fertilizer application.,Proc. Seminar: Production and Use of the Chemical Fertilizers and Environment.El Fouly. M.M. et Abdalla. F.E. (éds) Cairo (Egypte), 17-21 December 1994., 93-99 **(1995)**

3. Chien S.H. and Hammond L.L., A comparison of various laboratory methods for predicting the agronomic potential of phosphate rock for direct application, *Soil Sci. Soc. Am. J.,* **42**, 1758-1760 **(1978)**

4. Chien S.H., Solubility assessment for fertilizer containing phosphate rock, *Fert Res.,* **35**, 93-99 **(1993)**

5. Khasawneh F.E. and Doll. E.C., The use of phosphate rock for direct application to soils, *Adv. Agron,* **30**, 159-206 **(1978)**

6. Zapata F., Evaluating the agronomic effectiveness of phosphate rocks using nuclear and related techniques: results from a past FAO/IAEA Coordinated Research Project. *In* IAEA. ed. *Management and conservation of tropical acid soils for sustainable cropproduction,* 91-100. IAEA-TECDOC-1159. Vienna. IAEA **(2000)**

7. Zapata F., Utilization of phosphate rocks to improve soil status for sustainable crop production in acid soils, Special issue, *Nut. Cyc. Agroecosys,* **63(1),** 1-98 **(2002)**

8. Bariand P., Cesbron F. and Geffroy J., Les Minéraux 2, Minéraux de concentration d'éléments communs et d'éléments rares, Minéraux et fossiles. UTF-8 / MARC-8 **(1978)**

9. Truong B. and Fayard C., Small scale fertilizer production units using raw and partially solubilized phosphate, *In* H. Gerner A, U, Mokwunye. ed. *Use of phosphate rock forsustainable agriculture in West Africa*. pp. 181-198. Miscellaneous Fertilizer Studies No.11, Muscle Shoals, Alabama, USA. IFDC Africa (**1995)**

10. Bhatt M. and Chanda S.V., Prediction of leaf area in Phaseolus vulgaris by non-destructive method, *Bulg. J. Plant physiol,* **29**, 96-100 **(2003)**

11. Temdjim R., Njilah I.K., Kamgang P., Nkoumbou.C., Données nouvelles sur les laves felsiques de Ngaoundere (Adamaoua. ligne du Cameroun): chronologie k-ar et pétrologie AJST, Vol 5, N° 2, December **(2004)**

12. Tchameni R., Pouclet A., Penaye J., Ganwa A.A. and Toteu S.F., Petrography and geochemistry of the Ngaoundéré Pan-African granitoïds in central North Cameroon: implications for their sources and geological setting, *J. African Earth Sci.,* **44**, 511-529 **(2006)**

13. Nkouandou O.F., Pétrologie du volcanisme au nord et à l'est de Ngaoundéré. Thèse Université Pierre et Marie Curie (Paris-6). 120p + annexe **(2006)**

14. Smyth J.J., Sanchez P.A., Phosphate rock dissolution and availability in Cerrado soils as affected by P sorption capacity, *Soil Sci. Soc. Am. J.,* **46**, 330–345 **(1982)**

15. Sahrawat K.L., Jones M.P. and Diatta S., Extractable phosphorus and rice yield in an Ultisol of the humid forest zone of West Africa, *Common Soil Sci. Pl. Anal,* **28(9-10),** 711–716 **(1997)**

16. Abekoe M.K. and Sahrawat K. L., Phosphate retention and extractability in soils of the humid zone in West Africa, *Geoderma,* **102**, 175–187 **(2001)**

17. Djadjaglo C. and Richter., Efficacité de prélèvement du phosphore par les plantes Sorghum bicolore (L.) Moench et Phaseolus Vulgaris L. Production végétale, *Agro Solutions,* **l19**, 2 **(2008)**

18. Antoun H., Bordeleau L.M. and Gagnon C., Antagonisme entre le Rhizobium meliloti et le Fusarium oxysporun en relation avec l'efficacité symbiotique, *Can. J. Plant Sc,* **58**, 75–78 **(1978)**

19. Buonassisi A.J., Copeman R.J, Pepin H.S. and Eaton G.W., Effect of Rhizobium spp. On Fusarium f.sp. phaseoli, *Can. J. Plant Path.,* **8**, 140–146 **(1986)**

20. Ehteshamul-Haque S. and Gaffar A. Use of rhizobia in the control of root rots diseases of sunflower, Okra Soybeanand mungbean, *J. Phytopathology.,* **138**, 157–163 **(1993)**

21. Gervy R., Les phosphates et l'agriculture. Edition DUNOD. Paris, 298 **(1970)**

22. Hammond L.L, Chien S.H. and Mokwunye A.U., Agronomic value of unacidulated and partially acidulated phosphate rocks indigenous to the tropics, *Adv.Agron.,* **40**, 89-140 **(1986b)**

23. Fardeau JC., Dynamique du phosphore et du potassium dans le système sol-plante. Dans « Fertilisation P-K: raisonner pour agir ». ARVALIS Institut du Végétal., 12 **(2005)**

24. Johnson P., Foliar phosphate applications to potatoes. Symposium on plant health and the european Single Market, Reading Royaume Uni **(1993)**

25. Morel J.L. and Fardeau J.C., Pouvoir fixateur des sols vis-à-vis du phosphore : conséquence sur la fertilisation phosphate, *Perspectives Agricoles.,* **147**, 65-72 **(1990)**