Original Research Article

The Influence of basalt powder on the physicochemical properties of impoverished oxisoils from Ngaoundéré (Adamawa - Cameroon)

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ABSTRACT

The present study aims at assessing the fertilizing potential of basalts on impoverished oxisoils from Ngaoundéré (Adamawa, Cameroon). This specifically involves the application of finely ground basalts on impoverished oxisoils and monitoring changes in physicochemical properties during six months. An experimental design which consisted in a randomized complete block design is constituted of three series of four treatments each one: the control (ST), the control soil mixed with 100 g of finely ground basalt (T0 + BA_10), the control soil mixed with 200 g of finely ground basalt (T0 + BA_20), the control soil mixed with 300 g of finely ground basalt (T0 + BA_30). Each treatment was replicated ten times in every serie. The control treatment is only soils of Ng, collected at the top soil and without any basalt application. They are clayey, acid and display an average CEC. The basalt is rich in silica (47.52%), Calcium (8.22%), Magnesium (4.03%), sodium (4.01%), potassium (2.42%) and displays average content in alumina (16.54%) and iron (11.1%). The experiment was carried out in pots, and the incubated soil samples were analyzed after 0, 1, 2, 4 and 6 months. The analyzes mainly focused on the physicochemical parameters (Grain size analysis, pH, Cation exchange capacity (CEC), the sum of exchangeable bases (SBE) and the saturation rate (V). Obtained results indicated that the application of basalt greatly improved the chemical properties of oxisoils from Ngaoundéré: the pH changes from acidic (5.5) to weakly acidic (6.5); the saturation rate, as well as the sum of exchangeable bases and the cation exchange capacity increased. Physicochemical properties of the soil are closely accompanied by an increase in fertility. It appears that 10 and 20% treatments are the most efficient treatments. Thus, the basalts from Manwi can be recommended as petrofertilizer to improve the chemical properties of impoverished soils and especially for plants requiring alkalis and alkaline earth.

Keywords: Ngaoundéré, Cameroon, basalt, incubation, oxisoils, fertility

1. INTRODUCTION

A productive and sustainable agricultural system is fundamental for the well-being of a nation and is a cornerstone of its development [1,4]. In most African countries, more than half of the population depend on agriculture for their livelihoods, yet soils are overexploited [1,4,19,20,35]. In order to ensure continued soil fertility, it is evident that the soil nutrients exported by plants must be greater than or equal to the imported soil nutrients [1,21,35]. But in most African countries, more soil nutrients are exported than replenished. This is why [2] said that soils in most cases are "exploited". To increase soil productivity, farmers must not only increase nutrient concentrations in the soil but also improve soil structure, and reduce soil loss. Arable land is shrinking at a rate of about 5-10 million hectares per year, and this during a period of global population growth [3]. Increasing sustainable food production requires in-depth knowledge of soils, the appropriate use of available resources, prevention of degradation and restoration of degraded soils [4].

The diagnosis of oxisoils fertility from Ngaoundéré in particular, revealed a low rate of fertility due to the natural conditions of their formation, and a decrease of that fertility rate due to poor soil management which, insidiously, induces their physical, chemical and biological degradation [5,6]. The soils from Adamawa region belong to the large group of ferralitic soils [7]. They are formed through the processes of allitization and monosiallitization following the high rainfall and the very rugged character of the relief of this region. There is therefore, an almost total evacuation of exchangeable bases and silica leading to acidification of the soils. Faced with the problem of declining soil fertility and crop yields, the high costs of mineral fertilizers and above all the pollution of the environment by so-called conventional fertilizers, it is imperative or even essential to find other fertilization alternatives, such as rocks powders [8,9,10,11,12,13,14,15,16,17,18,4,19,20,21,22,23,24,25,26]. Oxisoils occupy most of the region, these soils are exploited in several areas of life: as materials for construction and also for agriculture. Because of agricultural intensification and inadequate agricultural practices, they are subject to erosion which mobilizes fines particles and nutrients. The restoration of their fertility will consist to address the problem of decline nutrients [27,28,29]. The aim of the present study is to investigate the effect of the application of fine ground basalt on the physicochemical properties of oxisoils from Ngaoundéré.

2. MATERIAL AND METHODS

2.1 Soils sites and sampling

The soil was sampled at the level of the topsoil (0 to 25 cm) on an unproductive plot at Manwi, a locality situated at about 15 km from Ngaoundéré town (Figure 1). So, soils were collected at different points of the surface horizons, and a composite soil sample was obtained by mixing all the sample and quartered. Finely ground basalt used as fertilizing material was obtained by crushing blocks of unaltered rocks. They were also collected at Manwi; their main interest emanated from their local availability, accessibility, low exploitation cost and wide geographic extension.

2.2 Soil and rock analyses

The soils were air-dried, mixed and quartered in order to obtain samples which are representative of oxisoils from Ngaoundéré. Physicochemical analysis was carried out on air-dried soils samples ground to pass a 2 mm sieve and consisted to determine grain size analysis, pH, exchangeable bases, cations exchange capacity (CEC). Those analyses were carried out at soil laboratory of the university of Dschang, Cameroon.
Particle size distribution was determined by the pipette method following dispersion with sodium hexametaphosphate. Soil pH_{H2O} was measured with pH meter equipped with a glass electrode in 1:2.5 soil-water suspensions. Exchangeable basic cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) were extracted using a neutral (pH_{water} = 7) ammonium acetate solution and their quantity measured by flame emission and atomic absorption spectrometry. The sum of all the exchangeable basic cations was deducted as follow $S= Ca^{2+}+ Mg^{2+}+ Na^{+}+ K^{+}$. The cation exchange capacity (CEC) was determined using a neutral ammonium acetate in three stages: saturation of the absorbent complex with NH^{4+} ion and extraction of exchangeable basic cations; elimination with alcohol of the saturating NH^{4+} solution filling the holes of the sample; measurement of NH^{4+} with Kjeldahl distillation after a quantitative desorption with

KCl. The saturation rate was deducted from the exchangeable basic cations sum (S) and the cations exchange capacity (CEC) as follow (S/CEC in %).

Geochemical analysis of Basalt from Manwi was carried out at CRPG Nancy (France). The major elements were determined by inductively coupled plasma atomic emission spectroscopy (ICP AES) while trace elements and rare earths elements (results not shown) were determined by inductively coupled plasma mass spectrometry (ICP-MS).

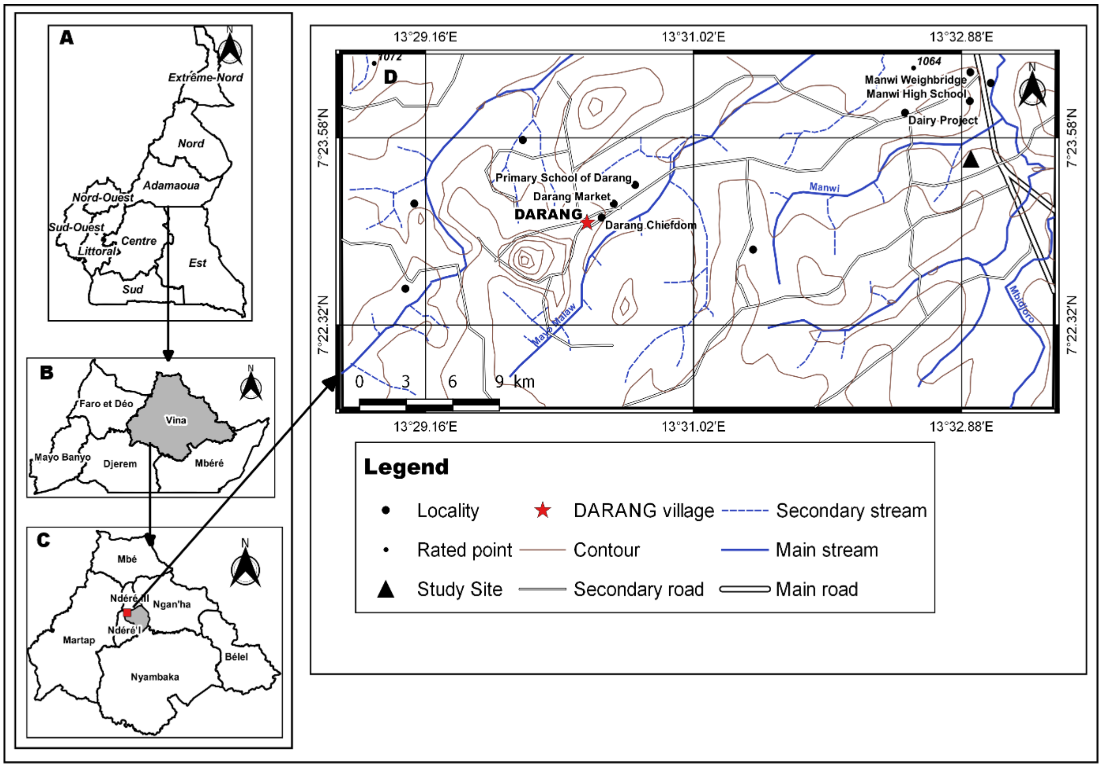

Figure 1: **Localization of study area** (*obtained from SOGEFI 2019 database coupled with topographic map of Ngaoundéré at 1:200,000, associated with field data*).

2.3 Experimental design

A pot experiment was carried out in the familial greenhouse at Manwi near Ngaoundéré university (N 07 41°; E 13 55°), located at about 15 km north of Ngaoundéré town. 1 kg of composite oxisoil sample soil was put in pot containers. An experimental design is a triplicated randomized block design constituted by four treatments each one: the control (ST), the control soil mixed with 100 g of finely ground basalt (T0 + BA_10), the control soil mixed with 200 g of finely ground basalt (T0 + BA_20), the control soil mixed with 300 g of finely ground basalt (T0 + BA_30). Each treatment was replicated ten times in every serie. The control treatment is only soils of Manwi without any basalt application. The soils are watered at field capacity. The pots were arranged in rows according to treatments and 5 cm spaced between two series in a completely randomized block. In total, sixteen (60) pots were studied. The physicochemical parameters of the studied soils are measured ~~after~~ at 0-month, 1 month, 2 months, 4 months and 6 months of incubation.

3. RESULTS

3.1. Physicochemical properties of Ngaoundéré's oxisoils

Particle size results are gathered in table 1. It appears that oxisoils from Ngaoundéré have a higher content in clay (53%) and average amount of silt and sand (19% of silt and 28% of sand). These soils are clayey, acid and displayed an average CEC (32.52 cmol/kg) and bases saturation rate (68%). They have relatively low levels of Magnesium, Potassium and Sodium.

Table 1: Physicochemical characteristics of Ngaoundéré's oxisoils.

Physicochemical parameters	Clay	Sand	Silt	pH	Ca	Mg	K	Na	SBE	T (CEC)	V=S/T
	%	%	%		cmol/kg	cmol/kg	cmol/kg	cmol/kg	cmol/kg	cmol/kg	%
Content	53	28	19	5.5	16	2.88	2.31	0.79	21	32.52	68

3.2. Geochemical composition of basalt

The geochemical analysis of the basalts from Manwi (West of Ngaoundéré) (Table 2 and Table 3) shows that they are rich in silica (47.52%), Calcium (8.22%), Magnesium (4.03%), sodium (4.01%), potassium (2.42%) and displays average content in alumina (16.54%) and iron (11.1%). Some trace elements (Ba, Ni, Sr, Zr, …) are present in average content (Table 3). Those major elements are essential for the regeneration of impoverished soils, participate in the formation of the clay-humic complex of soils, stimulate microbial activity in soils and finally revitalize tired soils.

Table 2: Major elements (in %) of basalts from Manwi. LOI: loss on ignition

Sample	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
	47.52	16.54	11.1	0.23	4.03	8.22	4.01	2.42	2.62	1.31	2.17	100.18

Table 3: Traces elements of basalts from Manwi

	Ba	Ni	Sr	Zr	Y	Nb	Sc
Elements	ppm	ppm	ppm	ppm	ppm	ppm	ppm
	1037	21.69	1730	368.6	38.25	92.98	0.367

The results of soil incubations with basalt powder are presented in table 4 and figure 2. It shows different level of soil physicochemical properties improvement.

3.3. Effect of basalt powder application on soil pH

After applying basalt powder to the soils, the amended soils had in general a significantly higher soil pH (at least 0.5 units) than the control sample throughout the incubation period (Figure 2a).

Table 4: **Soil exchangeable bases, pH and CEC as a function of time of amended basalt-based soils for the application rate of 10%. 20% and 30% compared to those of the control soil.**

	Incubation time in months	0 month	1 month	2 months	4 months	6 months
Treatment at 10%	**Parameters**	**T0**	**BA1-10**	**BA2-10**	**BA4-10**	**BA6-10**
	Ca (cmol/Kg)	16	17.92	17.28	9.52	7.52
	Mg (cmol/Kg)	2.88	3.36	2.72	1.12	3.04
	K (cmol/Kg)	2.31	14.61	2.52	0.35	0.91
	Na (cmol/Kg)	0.79	1.94	0.92	0.2	0.2
	SBE (cmol/Kg)	21	37.83	23.44	11.19	11.67
	T(CEC) (cmol/Kg)	32.52	44.72	31.28	23.2	30.56
	Saturation rate (%)	68	85	75	48.25	38.18
	pH	5.5	5.7	5.9	6.5	6.1
Treatment at 20%	**Parameters**	**T0**	**BA1-20**	**BA2-20**	**BA4-20**	**BA6-20**
	Ca (cmol/Kg)	16	18.88	16.32	10.16	9.6
	Mg (cmol/Kg)	2.88	3.84	3.52	0.96	1.6
	K (cmol/Kg)	2.31	2.8	2.52	0.35	0.35
	Na (cmol/Kg)	0.79	1.04	0.89	0.2	0.2
	SBE (cmol/Kg)	21	26.57	23.25	11.67	11.75
	T(CEC) (cmol/Kg)	32.52	37.12	40.24	26.88	30.24
	Saturation rate (%)	68	72	58	43.41	38.85
	pH	5.5	6	6.1	6.1	6.1
Treatment at 30%	**Parameters**	**T0**	**BA1-30**	**BA2-30**	**BA4-30**	**BA6-30**
	Ca (cmol/Kg)	16	14.88	12.32	12.96	10.16
	Mg (cmol/Kg)	2.88	2.72	2.24	3.52	2.96
	K (cmol/Kg)	2.31	4	2.36	0.62	0.62
	Na (cmol/Kg)	0.79	1.07	0.73	0.2	0.2
	SBE (cmol/Kg)	21	22.67	17.67	17.3	13.94
	T(CEC) (cmol/Kg)	32.52	33.92	27.12	28	27.52
	Saturation rate (%)	68	67	65	61.78	50.65
	pH	5.5	6.1	6.1	6.2	6.1

For the application rate of 10%, after 1 month of incubation, there is an increase of 3.63% compared to the control. After 2 months of incubation, an increase rate of 7.27% compared to the control soil is recorded, and an increase rate of 3.50% compared to that of the first month is noted. After 4 months of incubation, the pH increases by 18.18% compared to the control, and 14.04% compared to that of the second month. After 6 months of incubation, the pH increase rate is 10.90% compared to the control, and 6.15% compared to that of the fourth month.

For the application rate of 20%, it is observed after 1 month of incubation, an increase of 9.09% compared to the control soil. After 2 months of incubation, the rate of increase is 10.90% compared to the control soil, and 1.66% compared to that of the first month. After 4 and 6 months of incubation, the increase is 5.30% compared to the control.

For the 30% treatment, the pH increases significantly the incubation period. After 1 and 2 months of incubation, an increase of 10.90% is observed, compared to the control soil. After 4 months, an increase of 12.72% compared to the control soil is recorded, and 1.63% compared that of the first and second month. After 6 months of incubation, the pH increases by 10.90% compared to the control soil. In general, the pH changes from acidic to weakly acidic.

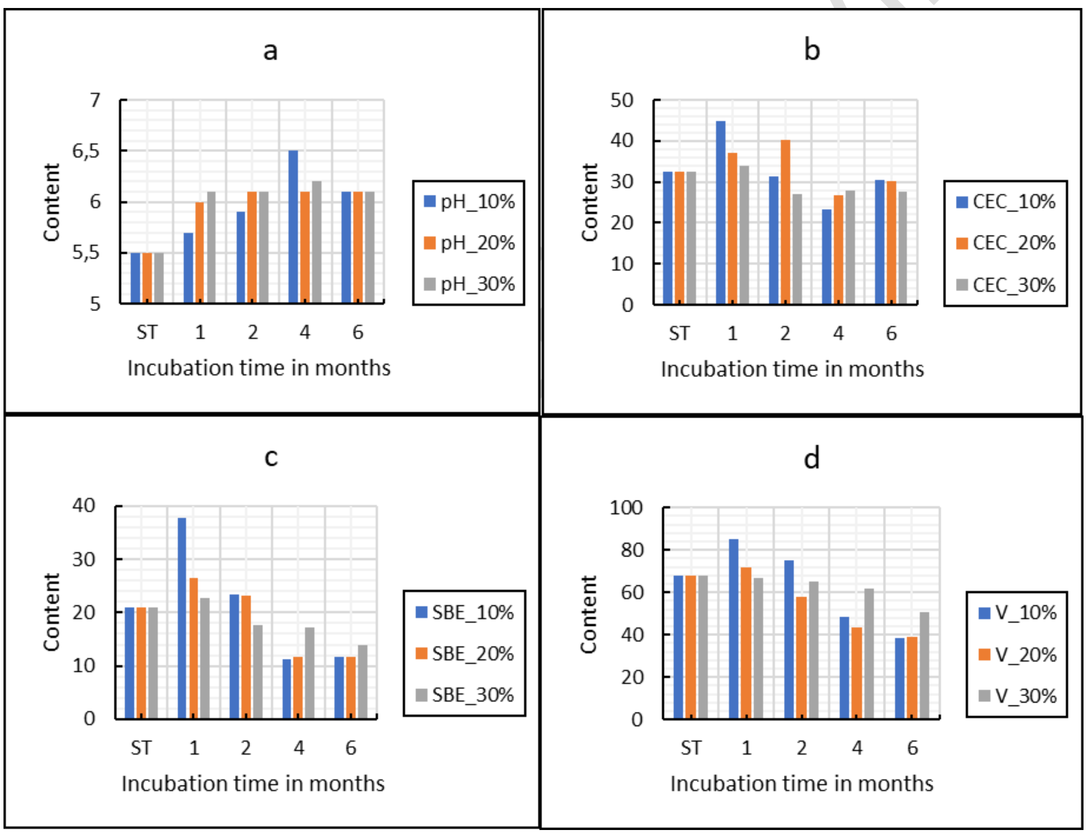

Figure 2: variation of: **a**) pH; **b**) Cationic Exchange Capacity; **c**) Sum of Exchangeable Bases and **d**) saturation rate per treatment.

3.4. Effect of basalt powder application on CEC

The CEC increases significantly after 1 month of incubation (Figure 2b). An increase of 37.51% is recorded compared to the control. After the 2, 4 and 6 months of incubation, the rate drops compared to the control. With regard to the 20% basalt treatment, there is a significant increase in CEC after the 1st and 2nd month of incubation being 14.14% and 23.73% respectively. For the treatment of 30%, there is an increase in the CEC after the 1st month of incubation only. After the 2nd, 4th and 6th month a regression of the CEC was recorded.

3.5. Effect of basalt powder application on the exchangeable cations pool

For the treatment of 10% basalt, the sum of exchangeable bases increases during the incubation period (Figure 2c). After 1 month, there is an increase of 80.14% compared to that of the control soil. After 2 months of incubation, there is an increase of 11.61% compared to the control soil, and a decrease of 68.53% is noted when compared to that of the first month. For the other months, a decrease of the sum of exchangeable bases was observed. For the 20% treatment, the sum of exchangeable bases evolves positively throughout the incubation period. After 1 month of incubation, the increase in the sum of exchangeable bases is evaluated at 26.52% compared to the control soil. After 2 months of incubation, an increase of 10.71% is observed when compared to the control soil, and a decrease of 12.49% is noted when compared to that of the first month. After 4 months of incubation, there is a decrease of 44.42% and after 6 months of incubation, there is a decrease of 44.04%, but an increase of 0.68% when compared to that of the fourth month. The application of 30% of basalt powder induces an increase of 7.95% in the sum of exchangeable bases, after 1 month of incubation, compared to the control soil. After 2, 4 and 6 months, there is a decrease compared to the control.

3.6. Effect of basalt application on the saturation rate

There is an increase in the saturation rate during the first, two months of incubation with the 10% treatment (Figure 2d). After 1 month of incubation, there is an increase of about 25% compared to the control soil. After 2 months, an increase in the saturation rate of 10.29% is observed comparatively to the control and a decrease of 11.76% is noted when compared to that of the first month. With the 20% treatment, the saturation rate after 1 month recorded an increase evaluated at 5.88% compared to the control soil. After 2 months, it decreases by 14.70% compared to the control soil, and a decrease of 19.44% is observed comparatively to that of the first month. After 4 months of incubation, there is a decrease estimated at 36.16% compared to that of the control soil. After 6 months, a decrease in the saturation rate of 42.86% compared to the control soil is recorded. The 30% basalt amendment leads to a decrease in the saturation rate evaluated at 1.47% compared to the control soil. After 2 months of incubation, the decrease is 4.41% compared to the control. After 4 months of incubation, a regression of 9.14% compared to the control is recorded. Finally, after 6 months of incubation, the regression rate is 25.51% compared to the control.

4. DISCUSSION

The studied soils from Ngaoundéré are clayey, acid and display an average CEC and low content in exchangeable cations; these are common properties of oxisoils [30]. The application of basalt powder induces a significant increase in pH during the experiment, it switches from 5.5 to 6.5, so the soil pH changed from acid to weakly acid pH [30]. These results are similar to those of [18] with basaltic pyroclastic. The work of [31,32,33,34] have shown that indeed, above pH 5.5, Al^{3+} becomes insolubilized. The observed decrease of the acidity of the amended soils with basalt powder can be linked to the release of basic cations, in particular Ca and Mg. The behavior of exchangeable bases (Figure 2c) and of the cation exchange capacity (Figure 2b) during the incubation period shows an increase in the rate of bases and of the CEC which is not proportional to the quantity of basalt powder added. These results are contrary to those of [18] who showed that an increase of the content of bases and CEC is proportional to the concentration of pyroclastic materials added. The most important concentrations observed in the amended soils are those of Ca^{2+}, followed by Mg^{2+} and finally K^{+} (Table 4) [18,19,20,21]. This implies a significant release of Ca and Mg contained in the basalts [18]. The low content of K can be explained by its low proportions in the rock used [20,21,35]. In general, the amendment of Ngaoundéré soil by finely ground basalt induces a rapid and significant increase of the contents of alkaline and alkaline-earth cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}). The K^{+} concentration increases rapidly and strongly; compared to the control. Increase rates of 73.16% are reached for the application rate of 30% after 1 month of incubation. The content of Na^{+} increases at an exponential rate during the incubation period compared to the control. In fact, it varies from 0.79 cmol/kg in the control soil to reach values of 1.04 cmol/kg and 1.07 cmol/kg for the 20% and 30% treatments respectively. Also, Ca^{2+} and Mg^{2+}contents, as observed, increase rapidly during the incubation period. The increase rate of Ca^{2+} is 18% with 20% treatment, after the first month; while that of Mg^{2+} is 33.33% compared to the control soil. This significant contribution of alkalis and alkaline earth metals can be explained by their relatively high contents in the basalts [21,35]. The increase in the content of exchangeable bases correlates positively with the increase in CEC [18,20,21,29]. The improvement of all of these chemical parameters of the soil is closely accompanied by an increase in fertility [18,19,20,21,29,35]. The 10 and 20% treatments appear to be the best concentrations for the improvement of the chemical properties of impoverished oxisoils from Ngaoundéré.

5. CONCLUSION

The studied soils from Ngaoundéré are clayey, acidic and display average CEC and low content in exchangeable cations. The application of basalt powder at different concentrations induces the improvement of the physicochemical properties of the amended soils: the soil pH changes from acid to weakly acid; the sum of exchangeable bases increases along with the CEC and the saturation rate during the incubation period. The 10 and 20% treatments appear to be the best concentrations for the improvement of the physicochemical properties of impoverished oxisoils from Ngaoundéré. The overall results indicate that basalt powder can be an interesting alternative petrofertilizers to very expensive chemical fertilizers.

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