EVALUATION OF THE AGRONOMIC PERFORMANCE OF okra (*Abelmoschus esculentus*): SELECTION AND FERTILISATION OF THE GROWING SITE

SUMMARY

Okra (Abelmoschus esculentus L Moench) is one of the most nutritious fruit vegetables. A study was carried out to determine the suitability of the soil in the locality of Nkoévome (southern Cameroon) to propose fertilisation strategies to help improve okra yields for sustainable agriculture. The study took place at the Nkoemvone station of the Institut de Recherche Agricole pour le Développement (IRAD). The plant material used was the Hire variety. The experimental design used was a randomised complete block design with 7 treatments repeated 3 times: T0 (no fertiliser application), T1 (275 kg/ha N), T2 (165 kg/ha NPK 20.10.10 + 150 kg/ha urea), T3 (10 t/ha (FP), T4 (5 t/ha FP), T5 (½ dose of mineral fertiliser (T2) + ½ dose of 10 t/ha FP (T3); T6 (½ dose of mineral fertiliser + ½ dose of 5t/ha FP (T3). The data collected were analysed using Genstat software. According to the results, the soil at the study site according to the WRB classification was of the Rhodic Ferralsols type and unsuitable due to the climate and fertility due to PH, CEC, and phosphorus which were at low levels in the soil. The treatments applied had a significant effect on growth parameters (width, length, number of leaves, branches), and on yields by weight and number of fruits of okra, but not on the diameter at the crown and the height of the crop. Thus, the organic fertilisers in this study significantly improved certain okra growth and yield parameters compared with different doses of mineral fertilisers and the control.

Key words: Okra, phosphorus, hen droppings, mineral fertiliser, soil suitability.

1 INTRODUCTION

The agricultural sector in Cameroon accounts for 22.9% of GDP and employs 62% of the working population [24]. It is characterised by a wide range of agricultural products, including vegetables in general and okra in particular. Okra (Abelmoschus esculentus (L.) Moench) is a plant cultivated in tropical and subtropical regions of the world [39]. It is an exceptional and original plant because all its parts - roots, stems, leaves, fruit and seeds - are used for food, medicinal, craft and even industrial purposes [22]. Among vegetables, it is a plant that provides products with a nutritional value that even exceeds that of the tomato [13] and [38]. Its high content of carbohydrates, proteins, vitamins A and C, iron, phosphorus, potassium and magnesium has been demonstrated by [14], [18] and [30]. According to [22], the young fruits of okra contain a mucilage with various properties as a dispersion stabiliser, blood plasma substitute and fluidifier for liquid and blood systems. The fresh fruits are rich in vitamin C and calcium, while dried fruits are rich in protein and vitamins A, B and C [27]. According to [4], okra fruit contains 86% water, 2.2% protein, 10% carbohydrates and 0.2% fat. Okra seeds are a source of oil and protein: In addition, some prospective and epidemiological studies have shown that a high intake of fruit and vegetables reduces the risk of cardiovascular disease, certain cancers and other chronic diseases [42]. Roasted okra seeds are used in certain regions of Nigeria as a substitute for coffee [40]. Worldwide production is estimated at 7.5 million tonnes, 69.7% of which is produced in Asia, mainly India [8]. In Africa, production is estimated at almost 2.18 million tonnes, 83% of which is produced in sub-Saharan Africa [8]. In Cameroon, okra is one of the most widely consumed vegetables in households, in response to strong national and regional demand [19]. Its production is 2.8 t/ha, in contrast to the ideal yield of 12-15 t/ha [8]. Okra cultivation in several tropical countries faces multiple constraints that negatively affect production [12]. According to [43], this crop is faced with a lack of adequate inputs, skilled labor, poor cultivation practices, declining soil fertility, climate change, disease and pests [43]. It is important to note that the low production noted above is closely linked to the decline in soil fertility, the most obvious negative effects of which are the decrease in organic matter associated with the reduction in the amount of nitrogen in the soil and the invasion of cultivated land by weeds [1]. However, maintaining soil fertility is essential to achieving and maintaining high crop yields over the long term [21]. However, increasing okra yields is becoming a major concern, given that demand for its by-products far exceeds supply [8]. The general observation is that growers are embarking on production without bothering to carry out a soil-climate assessment of their growing plot, which would make it easier to choose a suitable production site for a given crop and, ultimately, to implement a fertilisation strategy. Rigorous knowledge of soil and climate assessment enables better management of cultivated land, quantifies the degree to which a plot of land is suitable for certain uses depending on its requirements and characteristics [10], and serves as a reference for prescribing crops adapted to a specific soil in order to optimise agricultural yield per unit of land [20]. In view of these factors, and in addition to the fact that soil fertilisation with mineral or organic fertilisers improves soil properties for potential crop production, since it reduces the loss of nutrients such as nitrogen, which is an unstable element in the soil and is lost mainly through leaching, crop export, volatilisation or evaporation [7]. The aim of this study was to evaluate the agronomic performance of okra in order to recommend appropriate fertilisation that could increase yields in the locality of Nkoémvone, which is dominated by ferralitic soils.

2 MATERIALS AND METHODS

2.1 MATERIALS

2.1.1 Biophysical characteristics of the study area

The study was carried out at IRAD's Nkoemvone research station, established in 1949 in a forested area. The station is located between 11.1° and 12.2° W longitude and between 2.4° and 2.8° N latitude at an altitude of 630 m, 15 km from Ebolowa on the Ebolowa - Ambam road in the southern Cameroon region [5]. This site has an equatorial climate (Koppen-Geiger classification), with high annual rainfall of 1,755 mm, an average of 865.8 mm and an average temperature of 24.4°C [11]. This climate is divided into four seasons: A long dry season (December-March), a short dry season (June-August), a long rainy season (September-November), and a short rainy season (April-May).

Fig 1 : Localisation of the study site

2.1.2 PLANT MATERIAL

The plant material used is okra of the Hire variety, with the following characteristics: light green colour, first harvest 60 to 65 days after sowing (DAS); average height of 25 cm; quantity of seed per hectare equal to 1 kg; harvesting time of 1 to 2 months. This variety is one of the most widely used by farmers in the area.

Fig 2: Presentation of Gombo Hire seeds

2.1.3.1 Fertilisers used

The fertilisers used in our trial were organic and mineral fertilisers. Organic fertilisers included: hen droppings bought at 500 FCFA per 50 kg bag from farmers in the village of Nkoemvone. The mineral fertiliser used in our trial was 20-10-10 NPK and urea, which are the chemical fertilisers most commonly used by okra growers in the locality of Nkoemvone. In this study, the experimental set-up was that of randomised complete blocks with 7 treatments and three replications (Figure 2). The area of each experimental unit was 3 m long by 2 m wide, i.e. 6 m2 with a distance of 0.5 m between the experimental units and 1 m between the blocks. The total surface area was therefore 187 m^2.

Fig.3. Diagram of the experimental set-up

2.2- METHOD

2.2.1- Experimental set-up

2.2.2 - Treatments

The treatments used here for mineral fertilisers are doses recommended by manufacturers. The recommended dose for organic fertilisers in Cameroon is 10 tonnes/ha [34]. In the case of mineral fertilisers, we have two doses: the one recommended in Cameroon for okra is 275 kg/ha/Na [35]. This corresponds to 450 kg/ha NPK 20.10.10 + 400 kg/ha urea, and the dose for okra's NPK fertilizer requirements used by most fertilisers, i.e. 100 kg N, 10 kg P, 60 kg K, 80 kg Ca and 40 kg Mg per hectare [34], which corresponds to 165 kg/ha NPK 20.10.10 + 150 kg/ha urea. These rates were used to determine the extent to which okra yields could be boosted in the locality of Nkoémvone, where they are alarmingly low. The different treatments are shown in Table 1:

Table.1 Different ways of processing the experiment

Treatments	Fertiliser
T0	No input
T1	275 kg/ ha/Na (450 kg/ ha NPK 20.10.10 + 400 kg/ha urea)
T2	165 kg/ha NPK 20.10.10 + 150 kg/ha urea
T3	10 tonnes / ha of chicken droppings (FP)
T4	5 tonnes of ha droppings
T5	½ dose of mineral fertiliser (T2) + ½ dose of 10 t /ha FP (T3)
T6	½ dose of mineral fertiliser + ½ dose of 10 t/ha FP (T3)

2.2.3 Setting up the test

2.2.3.1 Site preparation

The experimental site was chosen and delimited on the basis of calculations of the total surface area occupied by the site beforehand. The following operations were carried out: manual clearing of the site, ploughing and preparation of the experimental units. The site was cleared on 20 April 2023. Ploughing took place the following day. Ploughing was carried out to a depth of 25 to 30 cm. Fertilisation was carried out by spreading hen droppings from 20.10.10 and urea.

2.2.3.2 Spreading organic fertilisers

The hen droppings were analysed at the environmental chemistry laboratory of the University of Dschang at the rate and applied at the rate recommended in Cameroon, which is 10 tonnes/ha, i.e. 6 kg per incorporated bed, and the tested rate of 5 tonnes/ha, i.e. 3 kg per incorporated bed. The NPK mineral fertiliser (20-10-10) was applied 14 days after sowing (DAS), while urea was applied at 35 DAS at the rates recommended by the manufacturers. For treatments T1 and T2, these two fertilisers were applied in increasing rates of 100 kgN/ha + 16.5 kgP2O5 and 275 kgN/ha + 45 kgP2O5. They were applied in a crown 5 cm from the plants.

2.2.3.3 Seed preparation and sowing

The seeds were sown manually at a spacing of 80 cm x 60 cm, i.e. a density of 20,833 bunches/ha. The okra was sown at 3 seeds per packet, as recommended by local growers during the surveys, and at a sowing depth of 2 to 5 cm. The plants were removed 17 days after sowing (JAS), and each bunch was left with a single plant selected as the most vigorous.

2.2.3.4 Plot maintenance

As rainfall was not constant enough, water was supplied by sprinkling with 3 watering cans containing 10 liters per bed according to the watering system used by [23] to make up for the deficit in rainfall, which was so unstable that it occurred every 2 days.

2.2.3.5 Phytosanitary treatment

Phytosanitary treatments were carried out in a preventive manner using fungicides and insecticides. Among these products we used plantineb (80 EC) at a dose of 2 tablespoons / 16-litre sprayer, cypercot (cypermethrin 100 EC) and K -optimal (aceamiprid 200 g/kg; SP. Phytosanitary treatment was applied as soon as the first attacks of disease and damage to okra leaves were noticed (2 weeks after sowing). Treatments were carried out every week, alternating with an insecticide (k-optimal or cypercot).

2.2.3.6 Harvesting and weighing the fruits

The okra fruits were harvested manually at maturity using a pair of scissors. The first harvest took place at 64 days before harvesting and subsequent harvests took place every 03 days [34]. In this study, 12 harvests were carried out. Fruits were considered ripe when they were tender and when their upper end could be easily broken off with a fingertip.

2.2.3.7 Data collection

Two parameters were taken into account: Growth parameters and yield parameters.

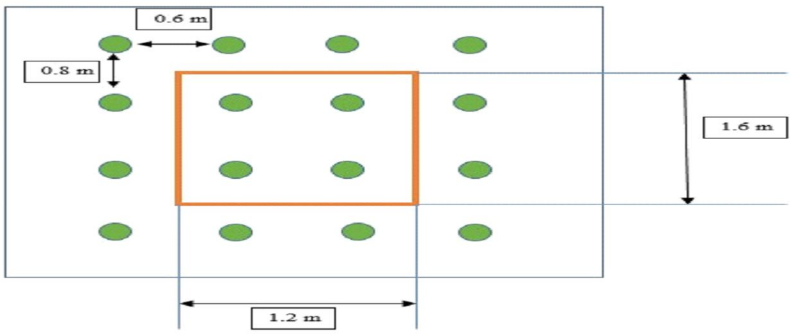
The data was collected as shown in the table below:

Table.2 Quantitative characteristics used for data collection

Characteristics	Periods	Methods
Plant height (cm) (HT)	3SAS to 7 SAS	Measured with a ruler
Stem diameter (mm)	3SAS to 7 SAS	Caliper measurement
Number of branches	3SAS to 7 SAS	Counting
Length of largest leaf (cm)	Length of largest leaf (cm)	Length of largest leaf (cm)
Width of largest leaf (cm) 3SAS to 7 SAS	Width of largest leaf (cm) 3SAS to 7 SAS	Width of largest leaf (cm) 3SAS to 7 SAS
Fruit weight (g) (Psd)	harvest	Weighing with a sensitive scale
Number of fruits per plant (NFr)	harvest	Counting
Fruit diameter (cm)	harverst	Measurement Using the calliper

2.2.3.8 Data collection system

The data were collected on 04 seed pods chosen in the center of each experimental unit (noted in orange) to minimize the border effect. The outer sowing line on each side was excluded for each experimental unit in order to delimit our sampling area.



2.2.3.9 Yields

- Ripe fruit weight

Using a digital balance, the cumulative weight of the ripe fruit harvest obtained from the 04 plants in the effective area was measured. The value of the crop weight of these plants in kilograms per hectare was determined by the following formula.

$$\textbf{Yield by weight} = \frac{\text{Cumulative yield of 4 plants X 10000}}{\mathbf{1,6}}$$

Number of ripe fruits

The number of fruits was obtained by counting the number of fruits for the 4 plants in the effective area. Once this number was obtained, it was reduced to the hectare by the following formula:

$$\mathbf{X} = \frac{\text{Number of fruits on 04 plants x 10 000}}{\mathbf{1,6}}$$

2.2 Soil sampling

Three composite samples of each soil block were taken from the trial in the said plot 0 to 30 cm deep using an auger before fertiliser application and 04 others using a ring in the soil profile preserved in polyethylene bags, and then sent to the Soil Analysis and Environmental Chemistry Laboratory of the University of Dschang for analysis. The following parameters were determined: pH-water, pH-kcl, total carbon, total nitrogen, total phosphorus, assimilable phosphorus and total potassium. 2.4 Laboratory analysis

2.5 Preparation of samples

Before the chemical parameters were measured, the soil samples were dried in the shade, weighed, crushed and sieved twice (02): once at 2 mm and again at 0.5 mm. The above-ground and below-ground biomass samples were also dried in the shade. They were then crushed and sieved directly to 0.5 mm.

2.6 Chemical analysis methods for soil samples

2.6.1 Granulometry

Granulometry consists of determining the different granulometric fractions of the soil (sands, clays, silts). It is carried out using the Robinson Köhn pipette method. The textural class is determined on the basis of the results obtained and using the USDA textural triangle according to [3].

2.6.2 PH

The pH was measured using a pH meter (potentiometer) fitted with a 'combined (pH) electrode', which is an electrode consisting of a combination of a glass electrode and a reference electrode [32]. The actual acidity or pH-water was measured in a sample-water suspension, while the total or potential acidity or pH-KCl 1M was measured in a sample-KCl suspension. Acidity was assessed according to Table 3.

Table .3 Assessment of acidity

LEVEL	pH value
Very acidic	<4,0
Acidic	4,0 – 5,3
Moderately acidic	5,3 – 6
Slightly acidic	6 – 7
Moderately alkaline	7– 8,5
Alkaline	>8,5

Source: Beernaert and Bitondo, 1992.

2.6.3 Organic matter

The determination of organic matter (OM) was based on the determination of organic carbon, given that the latter represents on average 58% of organic matter or that %CO x 1.724 = %MO. The WALKLEY-BLACK method described by [32] was used. It is based on the oxidation of organic carbon by potassium dichromate ($K_2Cr_2O_7$) in a strongly acid medium (H_2SO_4). The rate and quality of organic matter were assessed according to tables 3 and 4.

Table 4 Assessment of organic matter content

LEVEL	Very low	LOW	Medium	High	Very High
Value MO (%)	< 1,0	1,0- 2,0	2,0 – 4,2	4,2 – 6,0	> 6,0

Source: Beernaert and Bitondo, 1992

Table.5 Assessment of the quality of organic matter

Quality	Very poor	Poor	Good	Very good
Value C/N	>20	14 – 20	10 – 14	< 10

Source: Beernaert and Bitondo, 1992.

2.6.4 Total nitrogen

The total nitrogen content is determined by the modified Kjeldalh method, which consists of two stages: mineralisation of the soil, water, plant or animal tissue sample under heat in a mineraliser in the presence of a sulphuric acid-salicylic acid mixture, sodium thiosulphate and a catalyst. This is followed by titration. Finally, determination by distillation, which consists of stripping off the nitrogen vapour in the form of NH3 after alkalising the mineralised extract with NaOH. The distillate is captured in boric acid and titrated with H2SO4 0.01N until the initial colour of the indicator (red) returns. The total nitrogen is assessed according to Table 6.

Table.6 Assessment of total nitrogen

level	**Very poor**	poor	**Medium**	high	**Very high**
Value N(%)	< 0,050	0,050- 0,125	0,125 – 0,225	0,225 – 0,300	> 0,300

Source: Euroconsult, 1989.

2.6.5 Exchangeable bases

The exchangeable bases Ca++, Mg++, K+ and Na+ were extracted from the soil by saturation with a 1N ammonium acetate (NH4Ac) solution, determined by complexometry for Ca++ and Mg++ ; and by flame spectrophotometry for K+ and Na+ [32]. Exchangeable base contents were assessed using Table 7.

Table 7 Assessment of exchangeable base content in soil (meq/100g soil)

Level	**Ca^{++}**	**Mg^{++}**	**K^{+}**	**Na^{+}**
Very high	>20,0	>8,0	>1,2	>2,0
high	10,0 – 20,0	3,0 – 8,0	0,6 – 1,2	0,7 – 2,0
Medium	5,0 – 10,0	1,5 – 3,0	0,3 – 0,6	0,3 – 0,7
poor	2,0 – 5,0	0,5 – 1,5	0,1 – 0,3	0,1 – 0,3
Very poor	<2	<0,5	<0,1	<0,1

Source : *Euroconsult, 1989*.

2.6.6 CEC and base saturation rate

The CEC is determined using a solution of NH4Ac 1N at pH 7 in 4 steps: saturation of the adsorbent complex with the NH4+ ion and extraction of the exchangeable bases; washing of the soil with alcohol to eliminate the saturating solution; quantitative desorption with K+ and determination of the NH4+ by Kjeldalh distillation. The saturation rate V is deduced from the sum of the exchangeable bases S and the CEC at pH7 using the formula V(%) = 100*S/CEC. The sum of the exchangeable bases, the CEC and the saturation rate were assessed as shown in

Table 8.

Table 8 Assessment of S, CEC and V

Level	S (méq/100g soil)	CEC (méq/100g soil)	V (%)
Very poor	<2	<5	0 – 20
poor	2 – 5	5 – 10	21 – 40
Medium	5 – 10	10 – 25	41 – 60
high	10 – 15	25 – 40	61 – 80
Very high	>15	>40	81 – 100

Source: Beernaert et Bitondo, 1992.

2.6.7 Assimilable phosphorus

This is determined by the Bray 2 method, which combines extraction of P in an acid medium with complexation of aluminium bound to phosphorus by ammonium fluoride. The extraction is carried out using 0.03M NH4F + 0.1 M HCl. After complexation, the assay was carried out by UV spectrophotometry using molybdenum blue, and the reading was taken at 665nm. The assimilable phosphorus content was assessed using Table 9.

Table 9 Assessment of assimilable phosphorus content

Level	very poor	poor	Medium	high
Concentration P (ppm)	< 7	< 16	< 46	> 46

Source : Euroconsult, 1989.

2.6.8 Description of the soil profile

The soil profile was drawn up with dimensions of 2 m wide, 2 m long and 1.20 m deep at which the bedrock was reached. The profile was divided into 4 horizons, and the soil samples were taken using a 5-litre bucket, a hammer and a machete, and the rings were used to take the different soil density samples from these horizons. These horizons were described using the Munsell code. The various characteristics of the profile described are as follows. Colour, texture, structure, porosity, presence of stones, rooting, biological activity and limitations.

2.3 Soil and climate assessment of the study area

2.3.1 The climatic index

The climatic index (CI) was first obtained by grouping the various climatic characteristics of okra into two (2) groups, namely rainfall and temperature. This climatic index (CI) was then obtained using the square root formula according to [16]: CI= Rmin $\sqrt{([(X/100)*(Y/100)]}$) Where Rmin is the lowest value of all the groups; X, Y are the other lowest remaining parametric values of the other groups. The parametric climate value (VPc) is obtained by converting the CI according to the following relationships:

If 25 < CI < 92.5 VPc = 16.67+0.9 x CI

- If IC < 25 VPc = 1.6 x IC.

2.3.2 Final Terre evaluation

The final assessment is based on the calculation of the Earth Index (EI). Soil characteristics include both climatic and soil characteristics. For each crop, the soil characteristics are each given a parameter value based on the FAO requirements tables. The IT is also calculated using the formula in [16] , IT = Rmin $\sqrt{}$(X/100 xY/100x...) Where IT = Land Index, Rmin = lowest parametric value of the soil-climate groups, and X, Y, = other lower parametric values of the other soil-climate groups.

The IT value obtained is corrected (ITc) according to the following relationships [16] :

- If IT ≤ 25 ITc = IT
- If 25 < IT ≤ 50 ITc = 25+ (IT- 5) x 0.455
- If 50 < IT ≤ 75 ITc = 50+ (IT- 24) x 0.41
- If 75 < IT ≤ 100 ITc = 75 + (IT- 60) x 0.625

The habit classes are then arbitrarily defined according to the ITC. Table 10 shows the range of parametric values of the index associated with the degrees of limitation to the ability classes and the optimum performance.

Tableau 10 : Intervalle de valeurs paramétriques de l'indice associé aux degrés de limitation, aux

classes d’aptitudes et au rendement optimal

Index	Degree of limitation	Ability Classes	Optimum yield
100-90	0	S1-0 (High aptitude)	100-90
90-75	1	S1-1 (High aptitude)	90-75
75-50	2	S2 (Medium aptitude)	75-50
50-25	3	S3 (Marginal suitability)	50-25
25-0	4	N1 (Current unfitness)	25-0
	5	N2 (Permanent unfitness)	

Source : Sys et al (1991)

2.4 - Data analysis

Microsoft Excel version 2016 was used to enter the data and GENSTAT 9.2 was used to carry out the analysis of variance at the 5% threshold for the main test variables (growth and yield parameters); the smallest significant difference (LSD) was therefore used to compare the means of the treatments.

3 RESULTS AND DISCUSSION

3.1 RESULTS

3.1.2 Description and analytical results of the Nkoémvone soil profile

Table 10 presents the physicochemical characteristics of the different horizons in the profile of the study site.

Table 10 Physicochemical characteristics of the different horizons in the profile of the study site

Code sample	**AP**	**BA**	**BO1**	**BO2**
Depth (Cm)	**0 – 20 cm**	**20 - 47**	**47 - 90**	**90 - 130**
Laboratory code	**4**	**5**	**6**	**7**

Clay	80	85	90	85
Silt	10	11	8	11
Sand	10	4	2	4
Textural class	A	A	A	A
DA g/Cm3	0.868	1.350	1.418	1.608
Soil reaction				
C E (mS / cm)	0.02	0.04	0.05	0.01
pH-water	5	4.3	4.2	4.5
pH-KCl	3.9	3.7	3.6	3.9
Δ pH	-1.1	-0.6	-0.6	-0.6
Organic matter				
CO (%)	3.61	1.41	1.10	1.10
OM (%)	6.22	2.43	1.89	1.89
N tot. (%)	0.15	0.09	0.10	XS0.10
C/N	25	16	11	12
Exchangeable cations (meq / 100g)				
Calcium	4.00	3.00	5.04	5.20
Magnesium	2.40	2.80	2.16	2.00
Potassium	0.21	0.11	0.11	0.11
Sodium	0.11	0.11	0.05	0.05
Sum of bases	5.92	5.63	8.00	7.52
fCationic Exchange Capacity (meq / 100g) CEC pH7	28.00	27.00	25.00	28.00
	0.41	0.42	0.18	0.16
ESP(meq/100g)	21.14	20.84	31.99	26.85
Saturation (%)				
Assimilable phosphorus	16.24	3.51	4.12	6.46

A description of the profile shows that it is made up of 4 clearly subdivided horizons (AP, BA, BO 1, BO2), all with a clayey textural class.

The AP horizon has a depth of (0 - 20 cm), an acid PH of between (4.0-5.3), very high organic matter > 6.0, an average nitrogen content but of poor quality because C/N > 20. Exchangeable bases: calcium Ca 2+ is low (2.0 - 5.0), sodium Na + is very high (>2.0), magnesium Mg2+ is average (1.5 - 3.0 meq/100g soil) and potassium k + is low.

The BA horizon (20 - 47 cm) has an acid PH (4.0 - 5.3), average organic matter (2.0 - 4.2) of poor quality and a high cation exchange capacity (CEC) (25 - 40 meq/100g soil). Assimilable phosphorus is average, nitrogen content low, exchangeable bases (Ca 2+) low with a value in the range (2.0 - 5.0). Magnesium (Mg++) is average; potassium (k+) is low. CEC is high and base saturation low (V (%) with very low assimilable phosphorus.

The BO1 horizon (47-90) is characterised by a predominance of iron oxide, an acid PH, good quality average organic matter and a low nitrogen content. Exchangeable bases (Ca 2+ average, magnesium (Mg++)

average, potassium (k+) high, sodium (Na+) very low. CEC is high, assimilable phosphorus is average and base saturation is low.

The BO2 horizon (90 - 130 m) also has a predominance of iron and aluminium oxides. It has an acid PH, average organic matter of poor quality and a low nitrogen content. Exchangeable bases (Ca 2+ average, magnesium (Mg++) average, potassium (k+) high, sodium (Na+) very low. CEC is high and assimilable phosphorus is average. Organic matter (OM) is low but of good quality, with high CEC, low nitrogen and very low phosphorus.

3.1.2 Physico-chemical characteristics of the soil and amendment

Table 11 shows the results of analyses of the physico-chemical characteristics of the soil amendment and the study soil below.

Table. 11 Physico-chemical characteristics of soil and soil improver

Physico-chemical characteristics of the soil	**Amendments**	**Soil**			**Moyenne des blocs**
	Chicken droppings	**B3**	**B2**	**B1**	
Sample code	1	3	4	5	
Depth (Cm)	/	0 -30	0 -30	0 -30	
Clay	/	85	86	81	**84**
Silt	/	5	5	11	**7**
Sand	/	10	9	8	**9**
Textural class	/	Clay	Clay	Clay	
DA g/Cm3	/	/	/	/	
Soil reaction					
C E (mS / cm)	/	0.76	0.32	0.16	**0.413**
pH-water	8.2	5.1	4.4	4.4	**4.633**
pH-KCl		3.9	3.7	3.7	**3.77**
Δ pH		-1.2	-0.7	-0.7	**-0.87**
Organic matter					
CO (%)	33	3.61	3.48	4.24	**3.78**
OM (%)	66	6.22	6	7.3	**6.51**
Total N (%)	3.91	0.13	0.13	0.22	**0.16**
C/N	8	27	27	20	**24.67**
Exchangeable cations (meq / 100g)					
Calcium	3840	5.4	4.4	5.2	**5.00**
Magnesium	218.7	2	2.8	1.6	**2.13**
Potassium	1370.13	0.32	0.21	0.32	**0.28**
Sodium	1113.59	0.33	0.21	0.21	**0.25**
Sum of bases		6.06	6.81	8.53	**7.13**
CEC pH7		25	26	26	**25.67**
ESP(meq/100g)		1.33	0.81	0.81	**0.98**
Saturation (%)		24.23	26.21	32.82	**27.75**
Assimilable phosphorus					
Bray II (mg /Kg)	6626.56	14.29	18.27	15.29	**15.95**
Ash content (%)	34	/	/	/	/
Moisture content (%)	20	/	/	/	/

Source: Soil and Environment Laboratory, FASA, Uds, June 2023.

N.B.: Ca2+, Mg2+, Na+, K+, and soluble phosphorus are expressed in mg/kg for chicken droppings and rabbit droppings.

3.1.2.1 Physico-chemical characteristics of the soil

Table 11 shows that the soil analysed has a clayey surface texture. Its pH-water is acidic, and the ΔpH values (pH-KCl - pH-H2O) are all negative, indicating that the soil has a net predominance of negative charges, giving it good cation exchange capacity. The level of organic matter is very high (OM > 6.0). Nitrogen content is average (0.125 <N <0.225%). The C/N ratio is very poor (C/N>20%), potentially reflecting fairly slow mineralisation of organic matter by soil micro-organisms. The level of assimilable phosphorus is low (between 7 and 16 mg/kg). Therefore, a supply of the element phosphorus, either in organic or mineral form, would be a prerequisite for significantly increasing okra yields. Exchangeable cations K+ and Na+ are low [3]. The CEC (meq/100g) is moderate (25 < CEC < 40 meq/100g), the base saturation rate is low (21 < V<40 %).

4.1.3.2 Chicken droppings

The hen droppings used have a moderately alkaline pH (between 7.0-8.5); applying them to the soil would significantly raise its pH, making it even more favourable to the availability of plant nutrients. The organic matter content is high (>6%) and in exchangeable bases [3], and of very good quality (10 < C/N < 14). This would increase the effectiveness of the clay-humus complex in retaining nutrients and water. The nitrogen level is very high (>0.3). Thus the manure applied to the soil could possibly alleviate some of the chemical deficiencies present, and moreover it was applied a week before the okra was sown.

3.1.2 Evaluation of the study site for okra cultivation

3.2.1 Final pedoclimatic evaluation of okra

Table 12 presents the results of the final soil-climate evaluation of the study site for okra cultivation, based on the climatic requirements of the cotton site. According to the parametric method using the formula in [16], the pedoclimatic evaluation of the study site at Nkoémvone showed that the land used for okra production was currently unsuitable (N1cf) because of climatic and fertility constraints (base saturation rate). This limitation is very severe and not recommended.

Table.12 Final soil and climate assessment for okra.

Final soil assessment for okra				
	values	**classes**	**limitations**	**parametric values**
Slope	1%	S1-0	0	99
Flooding	F0	S1-0	0	100
Drainage	good	S1-0	0	100
Texture	Clay (Co)	S1-0	0	100
Coarse fragments	0	S1-0	0	100
Depth of soil	120 cm	S1-0	0	100
CaCO3	0	S1-0	0	100
Gypsum	0	S1-0	0	100
Apparent CEC clay	7.1	S3	3	60
Base saturation	50.7	S1- 1	1	85
CO	4.214	S1-0	0	100
PH	5.2	N2	4	25*

Electrical conductivity	0.12	S1-0	0	100
ESP	2.85	S1-0	0	99
Rainfed climate				19
	IT= 6,72			
	IT=7	N2 c,f		
Semi-irrigated climate				71
	IT= 14,89			
	ITC= 15	N2 c,f		

* = Lowest value of each climatic characteristic to be used in the calculation of the climatic index

NB: The pedoclimatic requirements used are those of cotton (Gossypium hirsutum) belonging to the Malvacae family in the appendix.

3.3 Effects of different treatments on okra growth parameters

3.3.1 Effects of treatments on okra leaf width

The analysis of variances of the data collected in Table 13 shows that the treatments applied had significant effects ($P \leq 0.05$) on leaf width during the different data collection periods. The separation of means shows that T3 was the best compared to all other treatments with the width of, 21.33 cm, 25.33 cm and 31.75 cm at 3.5.7 SAS. The T0 treatment had the lowest leaf width values (7.67cm, 14.67cm and 19cm respectively).

3.3.2 Effects of treatments on leaf length

The analysis of variances of the data collected in Table 13 shows that the different treatments applied produced highly significant values ($P=0.01$) during data collection. Separation of the means by Duncan's method shows a variation in the values of the different fertilisers on leaf length according to the different data collections. In the third week, the highest values were recorded in treatments T4 and T5 (15 cm and 14 cm). At the second week the largest values were recorded in treatments T5, T3, T4 (18.33 cm; 16.67 cm and 15.33 cm) and at 7 weeks we have T5 and T3 respectively (21.25 cm, 21.10 cm).

3.3.3 Effects of treatments on the number of leaves

The analysis of variance of the data collected in Table 13 shows that the different treatments applied produced significant values ($P \leq 0.05$) during the different data collections at week 7 SAS. The separation of the means shows that treatment T4 was better respectively 19.92 cm and T0 (10.67 cm) was the treatment with the least effect on the number of leaves.

3.3.4 Effects of treatments on crown diameter (mm)

Table 13 of the analysis of variances shows that the different treatments produced non-significant values ($P > 0.05$) during the different data collection periods for the diameter at crown parameter for all three weeks 3 SAS, 5 SAS and 7SAS.

3.3.5 Treatment effects on plant height

Table 13 presents the effects of the treatments on the height of okra plants over the three weeks after data collection. The analysis of variances indicates that the different treatments produced non-significant values (P > 0.05) on plant height during the three weeks 3 SAS, 5 SAS and 7SAS.

3.3.6 Effects of treatments on the number of shoots

Table 13 of the analysis of variance shows that the different treatments produced significant values (P≤0.05) over the three weeks (3SAS, 5 SAS and 7SAS) of data collection. The separation of means by Duncan's method shows that the different treatments produced values (P≤0.05) over all weeks. However, the highest average number of branches was observed in treatment T3, with an average of 6 at 3 SAS, 7.33 at 5 SAS and 9.33 at 7SAS respectively.

Table 13 Separations of averages in relation to their effect on okra growth parameters

Treatments	Input	Sheet width			Sheet length			Numb
		3 SAS	5 SAS	7 SAS	3 SAS	5 SAS	7 SAS	3 SAS
T0	No input	7.67a	14.67a	19a	6a	8.33a	12.67a	5a
T1	275 N kg/ ha	11.33ab	16.33ab	21.90ab	7a	9.67ab	14.67a	10.33a
T2	165 kg /ha NPK 20.10.10 + 150 kg / ha of urea	13.33bc	18.00abc	24.63abc	7a	10.67b	15.39bc	10a
T3	10 t / ha de (FP)	21.33d	25.33d	31.75d	11.67bc	16.67f	21.10c	13a
T4	5 t de FP	18.00cd	21.00bcd	27.35bcd	11.67bc	15.33def	19.98c	13.67a
T5	½ (T2) + ½10 t /ha FP (T3);	19.67d	22.67cd	30.19cd	15cd	15.67def	19.69c	11.33a
T6	½ dose T2+ ½ 5t/ha FP (T3) ;	17.33cd	22.33cd	27.64bcd	11b	14.33cde	18.21bc	9a
		**	*	*	**	**	**	**ns**

Treatments	**input**	**Diameter of collar**			**Height of plant**		
		3 SAS	5 SAS	7 SAS	3 SAS	5 SAS	7 SAS
T0	No input	6.00**a**	7.33**a**	11.17**a**	14.00**a**	17.67**a**	23.11**a**
T1	275 N kg/ ha	6.00**a**	7.33**a**	11.17**a**	15.00**a**	18.00**a**	23.09a
T2	165 kg /ha NPK 20.10.10 + 150 kg / ha of urea;	4.67**a**	6.67**a**	10.18**a**	17.67**a**	20.33**a**	24.92**a**
T3	10 t / ha de (FP) ;	6.00**a**	7.33**a**	9.08**a**	21.33**a**	24.33**a**	30.21**a**
T4	5 t de FP	8.00**a**	9.67**a**	12.32**a**	22.00**a**	25.67**a**	30.92**a**
T5	½ (T2) + ½10 t /ha FP (T3);	9.67**a**	11.33**a**	14.49**a**	24.33**a**	28.00**a**	33.85**a**
T6	½ dose T2+ ½ 5t/ha FP (T3) ;	8.33**a**	10.33**a**	13.24**a**	18.00**a**	21.00**a**	26.04**a**
		ns	**ns**	**ns**	**ns**	**ns**	**ns**

NB: Values bearing the same letters in a column are statistically equal; ns: not significant at 5%; **: highly significant at 5%; * significant at 5%.

3.4 Effects of different treatments on yield parameters

3.4..1 Fruit weight

The analysis of variance highlighted the different treatments that had a significant effect (P≤0.05) on the fresh weight of the fruit after harvesting. Figure (5) below presents the histograms and the cumulative yield curve of the evolution of fruit production according to the harvests. We can see that the bars of the histograms for the T3 treatment are the highest in all harvests combined during our study. This illustrates that T3 is the best treatment while the weakest treatment is T0 with the lowest histogram bars. The yields by weight obtained with treatment T3 increased progressively from 362 kg/ha at 64 DAS to 4175 kg/ha at 88 DAS, then decreased to 2125 kg/ha at the last harvest. Yields at T0 increased gradually from 125 kg/ha at 64 days before harvest to 233 kg/ha at the last harvest. When we look at this figure, we see a predominance of the colour yellow on the histograms corresponding to the 7th and 8th harvests, i.e. 88 JAS.

Fig.5. Evolution of yields in fruit weight according to harvests

The cumulative yield curve shows that the best treatments are T3 (13141kg/ha); T5 (12676kg/ha); T4 (11532kg/ha); T6 (11055 kg/ha) and those with the lowest yields are T0 (2513kg/ha); T1 (4996 kg/ha) and T2 (6973kg/ha). Figure 6 below shows the average yield of the different treatments.

Fig.6.Separation of fruit weight averages

NB: Treatments with the same letter are statistically equal and those not followed by the same letter are significantly different at the 5% probability threshold (P≤0.05) according to Duncan's test.

3.4.2 Number of fruits

Figure 7 below shows the evolution of fruit production over the 12 harvests. For the variable number of fruits harvested, a highly significant difference (P≤0.01) was observed at the end of the twelve harvests. The treatment with the highest number of fruits, as illustrated by the cumulative yield curve, was T3 with 565416 fruits, while treatment T0 had the lowest number of fruits, i.e. 113084 fruits. However, the highest number of fruits was obtained at 88 JAS, corresponding to the 7th and 8th harvests.

Fig.7. Evolution of yields in number of fruits according to harvests (number of

fruits/ha)

Separating the averages (Fig. 8), we can see that the best treatments in terms of number of fruits are T3 (565416 fruits/ha); T5 (525834 fruits/ha); T4 (470000 fruits/ha); T6 (467083 fruits/ha) and the lowest are T0 (113084 fruits/ha); T1 (220335 fruits/ha); T2 (336249 fruits/ha).

FIG.8. Separation of averages for number of fruits

NB: Treatments with the same letter are statistically equal and those not followed by the same letter are significantly different at the 5% probability threshold ($P \leq 0.05$) according to Duncan's test.

3.4.3 Fruit diameter

Figure 9 below shows the change in diameter as a function of the different harvests. It can be seen that no significant difference ($P > 0.05$) was observed between the effect of the different treatments during the twelve harvests. The results showed that T4 obtained the largest average diameter in fruit (1.68 cm), followed by T6 with an average of 1.59 cm, while T0 had the lowest average, with a value of 0.97 cm.

Fig. 9: Changes in fruit diameter at different harvests.

3.2 Discussion

3.2.1 Physicochemical characteristics of the soil

The soil on which okra was grown had a slope of 1% [36], which indicates that the value of the slope is low, so vulnerability to water erosion is also low. This shows that ridging on this type of slope would allow infiltration of a rainfall of 60 mm/h and store more than 100 mm of water in the soil. The texture of our soil was clay. This characteristic of the soil could be a limitation to cultivation, as okra adapts better to soils with a silty, silty clay or silty clay-sandy texture, but according to previous work by [6], [40]. Okra tolerates a wide variety of soils. The results of the chemical analyses of the soil showed that the soil was acidic, with a water pH value of 4.633, which should not be a constraint for okra cultivation, since according to some authors, such as [37], okra seems to be fairly tolerant of soil acidity. The organic matter content of the soil was very high (>6%), but of poor quality (14<C/N<20). This could not be a limit to okra growth, as it has been shown that okra acclimatises well to soils rich in organic matter [31]. On the other hand, poor quality organic matter may not contribute effectively to plant growth and development, as organic matter decomposes poorly with a C/N ratio of between 15 and 25 [28]. The CEC (meq/100g) is moderate (25 < CEC < 40 meq/100g), so its base saturation rate is low (21 < V<40%). The concentrations of exchangeable cations, including K+ (0.28 meq/100g soil), Na+ (0.25 meq/100g soil), Ca2+ (5 meq/100g soil) were low and Mg2+ average (2.13 meq/100g soil). The soil's cation balance was therefore (67/29/4), which was out of balance in favour of Ca2+ and K+, but against Mg2+. However, soil cation balance is reached when the ratio of Ca2+, Mg2+ and K+ is 76/18/6 [41]. The Phosphorus levels are low, which is a major factor in okra production on the site, given its importance for seed and fruit production.

3.2.2 Soil profile of the study site

The profile studied shows that our soil corresponds to the Rhodic Ferralsols in the classification system [9]. It generally corresponds to Oxisols in the USDA classification and to typical highly desaturated ferralitic soils or humus soils in the French system according to the Commission de pédologie et de cartographie des sols. In general, these soils are characterised by high acidity (pH-H20), low CEC, and low levels of exchangeable base and phosphorus. In addition, calcium levels obtained in all horizons are low, with an average of 4.31 [26], a result consistent with the opinions of other studies conducted in the South Cameroon region for cassava and plantain banana production. See [29].

3.2.3 Soil and climate assessment of the study site

The unsuitability class (N2cf) of the soil evaluation of the site under rainfed conditions can be explained by the insufficient rainfall during the crop cycle during this period. Under the semi-irrigated system, given that the soil evaluation for okra cultivation proved to be moderately suitable (S2cf), this situation could be explained by the regular inputs of water that we made during the trial period whenever it did not rain. The average suitability (S2cf) of the soil obtained under semi-irrigated conditions could be further improved and become a high suitability (S1) if, firstly, a water depth greater than or equal to 780 mm were applied throughout the plant's growing cycle, bearing in mind that in a Sahelian climate, okra's water requirements over the course of a complete growing cycle are of the order of 780 to 1000 mm [6]. Secondly, the cation balance, which had become unbalanced, was restored by applying adequate doses of soil improvers.

3.2.4 Effects of different treatments on okra growth parameters

3.2.4.1 Width, length, number of leaves, number of branches

Fertiliser application had a highly significant influence on leaf length, which was affected by treatments T5 (½ (T2) + ½10 t/ha FP), T3 (10 t/ha FP), which were the best for leaf number and leaf width, and finally for the number of shoots, T6 (½ dose T2+ ½ 5t/ha FP (T3)) was the best treatment. This could be explained by the fact that these treatments underwent advanced decomposition of the various fertilisers (organic and chemical) compared with the others and that the nutrients were released gradually despite the poor state of the soil. This phenomenon certainly contributed to the assimilation of nutrients by the plant. Over time, these nutrients are efficiently used by cultivated plants through an increase in leaf area and the photosynthesis process, as shown in previous studies [15].

3.2.4.1 Diameter at the crown and plant height

Fertiliser application had a non-significant effect on crown diameter and plant height during the three weeks of data collection. This can be explained by the fact that our soil was not significantly improved by the treatments despite a high level of organic matter, but of poor quality. This may not contribute effectively to plant growth and development (height and diameter at the crown), because for a C/N ratio of between 15 and 25, organic matter decomposition is poor [28]. This corroborates our work on soil and climate assessment, which showed that the soils at the study site are unsuitable in terms of fertility.

3.2.5 Effects of different treatments on yield parameters

3.2.5.1 Fruit weight, number and diameter

The effect of the amendment treatments (hen droppings) and the different combinations with chemical fertilisers showed a significant difference ($P \leq 0.05$) in fruit weight and highly significant ($P \leq 0.01$) in fruit number over the twelve harvests carried out. However, T0 (0 fertiliser application) gave the lowest yield in weight (2513kg/ha) and number of fruits (113084 fruits/ha) throughout our trial. This can be explained by the fact that the soil evaluation of the ferralitic soils of the Nkoémvone station for okra production was currently unsuitable (N1cf) due to climatic and fertility constraints (base saturation rate of $21 < V < 40\%$). This limitation is very severe and not recommended, and the lack of phosphorus in these soils would explain the non-significant values for fruit diameter. This corroborates the results of [23], who obtained similar results with T0 in his trial in a ferralitic soil on the identification of a number of organic and mineral fertiliser formulations that could be recommended to market gardeners growing okra in certain localities in western Cameroon. The T3 hen droppings (10t/ha) gave the best results in terms of fruit weight (13t/ha) and number of fruits (565/ha) throughout the trial, compared with the chemical fertilisers (T1, T2) and the different combinations (T5 and T6). This first confirms the hypothesis that 10 t/ha of okra is the best recommended rate of amendment for better okra production, which corroborates the recommendations of

[35]. In the same vein, [23] found a similar result with 11 t/ha of hen droppings on okra crop production. This can be explained by the fact that phosphorus is a limiting element in the ferralitic soils of Nkoémvone, which is one of the major limiting factors for production, and so according to the law of the minimum or LIEBIG's law, the importance of the yield of a crop is determined by the element that is found in the least quantity in the soil in relation to the needs of the plants [25]. Thus, the physico-chemical analyses of hen droppings showed a high phosphorus content, which compensated for the deficiencies in the soil by increasing its PH and cation exchange capacity (CEC), thereby increasing the yield in terms of weight and number of fruits compared with the doses of chemical fertilisers (T1, T2) and the various combinations (T5, T6). This could also be explained by the fact that the organic amendment satisfied the nitrogen and phosphorus requirements that regulate vegetative development [33], [2], compared with T5. We can therefore say that the organic fertiliser applied in this experiment created better conditions for crop growth and nutrition, as reported by [17].

4 Conclusion and outlook

At the end of this study, it is clear that production remains very complex and that the characteristics of the climate and soil must be taken into account. In the context of this trial, the soil description showed that the study soil corresponded to the Rhodic Ferralsols type, which generally corresponds to oxisols in the USDA classification and to typical highly desaturated ferralitic soils or humus soils in the French system, generally poor in calcium and phosphorus. The pedoclimatic evaluation showed that with insufficient rainfall during the experimental period, the study soil had an unsuitability class (N2c) under rainfed conditions. In addition, under the semi-irrigated system, the evaluation of the soil for okra cultivation turned out to be moderately suitable (S2cf). The final evaluation showed that the study site was unsuitable in terms of soil fertility and climate (N2cf). The various fertiliser treatments had a significant effect on growth parameters, i.e. leaf width (T3), leaf length (T5) and number of shoots (T6), but a non-significant effect on crown diameter and plant height during the data collection period. On the other hand, on the yield parameters, where the treatments had a non-significant effect on fruit diameter, (T4) was the best treatment. Yields in terms of fruit weight were highly significant and treatment T3 (10t/ha of hen droppings) was the best, with 13t/ha in fruit weight and 565416 fruits/ha compared with the different doses of mineral fertiliser and the control during data collection. We can therefore recommend an organic fertiliser dose of 10t/ha of hen droppings to the people of Nkoémvone.

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APPENDIX .1 Climatic requirements for cotton (150-160 day growth cycle)

Climatic characteristics	**Climate classes, degree of limitation and assessment**					
	S1 -0 **0**	**S1 - 1** **1**	**S2** **2**	**S3** **3**	**N1** **4**	**N2**
	900 – 1200	750 – 600 1200 – 1400	625 – 750 1400 - 1600	500-625 >1600	-- --	<500 --
Precipitation during growth cycle (mm)	35 -65	> 65 < 35				

	150 –300	100 -150 300 – 400	50 -100 > 400	< 50	-- --	< 15 > 34
Precipitation at vegetative stage 1st + 2nd month	< 25	25 – 50	50 - 75	75 -100	•	> 100
	> 26	24 - 26	22 - 24	20 - 22	---	< 20 --
Precipitation at yield formation stage 5th month	> 32	28 > 32	26 < 28	24 - 26	_	< 24
	> 34	30 - 34	< 30			
Precipitation at ripening stage (mm): 6th month	> 30	25 - 30	20 - 25	< 20		
Average temperature of growth cycle (C)	20 – 30	30 - 35	35 - 40	> 40		
Average maximum temperature of growth cycle (C)	12 -18	18 - 22	22 -27	> 27		
Average maximum temperature of the warmest month (c)	> 26	24 - 26	22 - 24	20 -22	-	< 20
Average temperature of the vegetative stage of the 1st month + 2nd month	0 - 50	50 - 65	65 -75	75 - 80	-	> 80

APPENDIX 2: Soil requirements for Cotton

Characteristics of the land	**Class, degree of limitation and ratio**					
	S1 -0 **0**	**S1 - 1** **1**	**S2** **2**	**S3** **3**	**N1** **4**	**N2**

	900 – 1200 • – 1 • 2 • 4 Fo good imperfect	• • •	• Moderate moderate	F1 Imperfect tense good	-- -- • Poor but drainable	<500 -- F2+ Poor not drainable

Topography	35 -65					
	C < 60s,SiC		C > 60v, SL	fs,S		
	Co,SiCL,		SCL	LS ,LCS		
	Si ,SiL,CL					
	0 – 3	3- 15	15 - 35	35 - 55	•	
	>100	5- 100	50- 75	25- 50	-	
	0 – 10	10- 20	20- 30	30 – 40	-	
	0 - 3	3- 6	6 - 10	10 - 15	-	
	> 24	15 - 24	< 16 (-)	< 16 (+)		
	80 - 100	100 – 80	35- 50	< 35		
	> 2.0	2- 2.0	0.8 – 1	35 – 50	<0.8	
	> 1.2	0- 8 – 1.2	<0.8			
	> 0.8	0- 4-0.8	< 0.4			
	6.3-7	6 0-6.3	5.8- 6.0	5.5 -5.8	•	
		7 1-7.5	7.5- 8.0	8.0 – 8. 2		
	0-8	8 – 10	10 -12	12 – 16	16 – 22	
	0 - 15	5 - 20	20 - 30	30 - 40	•	