ORGANIC AND MINERAL FERTILIZATION OF OIL PALM AT THE NURSERY STAGE

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Abstract

A series of three tests of organic and mineral fertilization application was carried out (2005 to 2007) at the industrial nursery of the CNRA research Station La Mé (5°26' N, 3°50' E, 23), in South-eastern Côte d'Ivoire. The first test was set up in completely randomized blocks and had only one factor consisting of four doses (0, 8, 20 and 35% by weight of the soil substrate) of cow dung (CD) incorporated in forest soil. The variables observed showed a positive trend of the effects according to increasing doses of CD. The second set up was set up with two factors completely randomized, according to a system composed of NPKMg (0, 62, 93 and 186 g/plant) and the CD (0, 25, 50 and 75%). In order to better target the optimum, the third test was set up with new doses of CD (0, 25, 30, 35 and 40%). The results observed with the parameters in the second set up showed a high variability of the effects of fertilizers combined to CD which was either in favour of low doses or in favour of high doses applied. Some high doses (50 and 75% CD) have sometimes induced negative effects on growth variables. The third test was characterized by constant differences between CD doses. This third set up enabled, by the best effects on the all of observed variables, the choice of dose 30% CD, as the optimum, without use of mineral fertilizers.

Keywords: Oil palm, nursery, cow dung, organic and mineral fertilization, optimal dose.

Introduction

The growth rate of oil palm seedlings depends fundamentally on the quality of set up technique adopted (Hossan *et al*., 2005). Balanced fertilization (Miller et Cramer, 2004; Satoru *et al.*, 2005) is a key part (Sekhara et Patil, 1980. Witt *et al*, 2005) of that set up technique.

Indeed, the best vegetative growth which is able later to induce higher productivity of the plant material is determined by an optimal mineral nutrition (Manna et al., 2005), which guarantees the coverage of the needs (Ouvrier, 1984) of the crop.

Although potassium chloride has an essential purpose in the process of productivity of oil palm, its contribution at the juvenile stage is of a major importance concerning growth through chlorine which plays a vital role in the proper functioning of photosynthetic activities (Eschbach *et al*., 1982).

This fertilization that can be mineral, organic, or a combination of both, should be better optimized in order to reduce as much as possible the cost price of the plant right out of nursery. This effort to reduce the cost price leads to resort to the use of different sources of organic matter including cow dung (CD), also known as dry cow dung. However, the use of this source of organic matter is profitable only in case of association of agriculture and animal husbandry. This association (Elaeis cultivation-animal husbandry) can help to improve productivity through active participation in the reconstruction of the organic stock in the soil (Hartmann *et al.*, 1998. Briggs and Twomlow, 2002). This practice enables also to reduce mineral losses due to lixiviation (Boaké and Ouvrier, 1995) and ensure better yields (Bonfils, 1963) on predominantly sandy particle size soils. Moreover, in the intensification systems, organic manure combined with mineral fertilization increases yields and stabilizes them from one year to another (Piéri, 1992).

The declining of soils fertility is often accompanied by a deficit of water balance and an increasing acidification (Berger, 1996) detrimental to the growth, development and production of crops.

However, making profitable the CD involves careful monitoring of satisfaction of the needs in water, sun and adequate temperatures. The application of this organic fertilization can be optimized by different combinations. These combinations are likely to result in a recommendation able to raise the challenge of better growth at lower cost (Péralta *et al*., 1985).

Indeed, the organic matter being one of the indicators of fertility, it plays an important role of soil resource through physical properties (Péralta *et al*., 1985) and in plant production (Feler 1995).

Regarding oil palm, nitrogen is the element whose need is primary from the juvenile stage (Belder *et al.*, 2005. Bellido *et al.*, 2005. Edwin et al, 2005. Vos *et al.*, 2005) until production starts, stage from which potassium becomes the crucial element for the improvement of the medium weight of bunches.

The CD may, for this purpose, be selected for nursery because of its relative high nitrogen content (at least 2%, unpublished internal report) compared to other sources of organic matter such as oil palm bunches and trunk. This organic and mineral fertilization study which has been subject to a series of three set up at the juvenile stage (from transplanting to the stage of transfer to the field) of oil palm seedlings aims at optimizing this source of organic matter.

This study is therefore about (1) seeking sufficient quantity of this source of fertilizers in mineral nutrition of oil palm tree at the juvenile stage and (2) the appropriate modalities of contribution of this CD for each nursery pot whose contents in soil (in the case of this study) is 25 kg. It is also about (3) comparing the effect of this fertilization on the growth parameters such as the collar girth (CG), the length of leaf number four (LL4) and the vigor index (VI) of seedlings. This will allow making decision about the optimal amount of CD to apply with or without mineral fertilizers during a nursery period of at least nine months. To these growth variables are added other parameters such as the stock of water in the bulb (MB) in the leaves (HL), in the roots (HR) of seedlings and the weight of dry leaves (WDL) which are studied in order to take into account their optimal improvement through organic and mineral fertilizer.

Materials and methods

The set up in general of an oil palm nursery follows a number of test including the availability and water conservation which plays a critical role. For this reason it is highly recommended to install nursery near a water source (Jacquemard, 1995) on an almost flat ground with a slight inclination towards that water source. This site configuration provides a natural drainage of the excess of water resulting either, from watering either, from a heavy rainfall. In the case here, the experiment was installed on the site of industrial nursery of the CNRA station which complies with all these conditions. The accurate determination of an optimal dose of CD-based fertilization required three different tests of the same type of set up. The quantities of CD were applied as a percentage of weight of soil. To achieve this, we had to determine the respective weights of soil and CD (annex (1) and (2)) from the volume of the nursery bag and the apparent density and weight of the mixture (annex (3) and (4)).

Stacking, collection of substrates and filling of nursery pots

Stacking was done in staggered rows following an equilateral triangle of 0.70 m side with Chinese bamboo stakes, the length between two adjacent lines is 0.60 m. Before filling the pots, the soil and dried CD were previously passed through a wire netting with five square millimeters of meshes. The collection of the CD was made during the dry season and packed in empty jute bags. The first test was made with CD exclusively (without mineral fertilizers) at the following doses: 0, 8, 20 and 35% CD of the soil. The need for more precise choice led to other set ups (second and third) including mineral fertilizers in composite form. Thus, the proportions applied in percentages of CD were: 0, 25, 50 and 75% for the second set up and 0, 25, 30, 35 and 40% for the third.

Experimental system

First set up

The system (Table 1) adopted is completely randomized with only one factor at 4 levels (0, 8, 20 and 35%) of treatments of CD mixed with the soil of the nursery pot content with 6 repetitions. The quantities of CD put in (8 to 35%) took into account the nature of tertiary sands whose rates reached 80% of the soil, over the first 100 cm (Berchoux et Lécoustre, 1986).

Second and third set up

The experimental system (Table 1) adopted for the last two set ups was factorial with two factors having each 4 levels of mineral fertilizers and, respectively 4 and 5 levels of CD with 5 repetitions, that is respectively 80 and 100 treatments. Each treatment consisted of six seedlings. The composite fertilizer consisted of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) according to formula 3. 3. 2. 1. of 186 g per seedling. For the second and third set up, the doses were 0, 25, 50 and 75% (set up 2) and 0, 25, 30, 35 and 40% (set up 3) of CD combined with the 4 levels of mineral fertilizers (0, 62, 93, 186 g/plant).

The needs in water per day (Surre et Ziller, 1963 Mémento de l'agronome, 1991) of the seedling in a pot of twenty five kilograms was 625 ml.

The variables measured

The observations concerned the aerial parts of seedlings and focused on the collar girth (CG), the length and surface of leaf 4 (LL4 and SL4), the height of seedlings (HT), of the longest leaf (WLL) and the dry weight of leaves (DWL). The other measurements were made on the primary (RI) and secondary (RII) roots, the moisture of bulb (MB), roots (MR) and leaves (ML). Concerning the first set up, the skinning was done at the end of the ninth month. As for the second and third set ups, their skinning was also made at the end of the fifth and ninth month. The calculation of vigor indexes (VI) in annex (5) and (6) was carried out during the last set up.

Doses and frequency of composite fertilizer apply

The maximum amounts that regularly increased until the fifth month (Mutert *et al.*, 1999) consisted of composite fertilizers (N, P, K, Mg) of 0, 62, 93 and 186 g/plant from which it remained constant during the rest of the time of the seedlings in pots. Fractioned applies were made monthly in solution.

Measurements

The measurements of all variables were made once per month (Corley, 1975; Surre 1979; Rognon and Boutin, 1988 and Djéket, 2002) with a string, a big ruler. They were carried out by a team of two observers. At the end of the first experiment, the seedlings were stripped for determination of the fresh and dry weight per treatment.

Results

First set up

HR and HL parameters were significantly (p<5%) improved at the dose of 35% CD (Table 2).

For the other variables (LL4, RI, RII and MB) as shown in Table 2, these improvements (Figures 1, 2 and 3) occurred invariably at doses 20 and 35% CD applied without mineral fertilizers. The differences noted between objects were sometimes highly significant (p<1%) switching from the control to the highest dose. The coefficients of variation (CV (%) observed were relatively low (14.90 and 18.00) for LL4 and CG (Table 2) variables. However, for four of the seven variables, none of the two highest doses (20 and 35%) appeared to be sufficiently suitable to induce a significant increase (p<5%) of one another. The lack of preponderant influence between these two doses (20 and 35%) was illustrated by certain variables (RII MB) although their CV (%) were higher (Table 2) and corresponded to 33.40; 32.20.

The stock of water (Table 2 and Figure 1) contained in the bulb of seedlings (MB), in the leaves (ML) and the roots (MR) expressed as a percentage of dry weight also had a high variability. As for the leaves, the CV (%) was lower (20.50) than the bulb (32.30) and the same order of magnitude as those of primary and secondary roots (28.30 and 33.40).

Second and third set up

With the combination of the CD to mineral fertilizers (second and third set ups), the DWL at the twentieth week was gradually depressed (Table 3) with increasing doses of the mineral fertilizers applied switching from 62 to 93 g.

From the 16th to the 20th week (Table 3) the SL4 showed a tendency to linear growth in function of time but also a depreciation (Table 3) induced by the increase in doses of mineral fertilizers. In contrast, the 50% CD dose without mineral fertilizers in Table 3 provided the larger values of dry matter in each of the three measurement periods (16, 18 and 20th weeks).

In the same table 3 of set up 2, the vigor index (VI), calculated on the same measurement periods was not significantly (p<5%) improved at any dose. However, for the whole measurements, the unit treatment of 25% CD seemed to be the best combination that ensures greater vigor of seedlings from 16th to 18th weeks. Nevertheless, treatment 93 g/plant of composite fertilizers without CD presented at the twentieth week some results equivalent to that of 25% CD without mineral fertilizers.

In this Table 3 regarding the DWL (in kg) in the twentieth week, its value was significantly (p<5%) higher at dose 50% CD without composite fertilizers (NPKMg: 3.3.2.1)).

At the resumption of this study (third set up) of CD application combined with mineral fertilizers, all the parameters measured (HT, DC, WLL and VI) in Table 4 as well as LL4 in figure 3 LL4 were significantly (p<5%) improved both at doses of 30% and 35% CD without fertilizer.

However, the differences between the results of these treatments (30% and 35% CD without mineral fertilizers) were not significant while the unit apply of 35% CD without fertilizers, seemed to require an additional expense of 5% CD for growth improvement levels identical to those of 30%.

Dicussion

First set up

The growth variables were all improved significantly (p<5%) by treatments 20 and 35% CD on a set of seven growth variables measured (LL4, CG, RI, RII, MB, MR and ML). However, the effects of the maximum dose of 35% CD failed, beyond dose 20%, to improve significantly (p<5%) all the seven measured. Indeed, the differences observed between measured variables were not significantly different when switching from 20% to 35% CD. It is therefore clear that neither dose 20% nor 35% CD can be considered to be the optimum. Given the fact that only some variables were significantly (p<5%) improved by dose 35% while the difference (15%) between both doses of CD (20 and 35%) was so high that it became difficult to choose a truly optimal dose. Moreover, it appeared that the variables (MR and ML by 35% CD) seemed to suggest that their significant improvements (p<5%) were function of increasing doses to a certain limit. To better locate the optimum, it became necessary to increase the apply dose of CD beyond 35% during a new set up.

Second implementation

With this second set up, the dose (50%) performed better and could be chosen as the optimum, but it appeared that the IV was significantly improved first, at the 16^{th} and the 18^{th} week with a dose of 25 % and, thereafter, at the 20^{th} week for dose E2 (93 g/plant NPK Mg) without CD. Under these conditions, none of the three doses can be selected as the optimum. It appeared that dose 50% CD was too high and indicated that the improvement of the variables was no longer function of increasing doses yet, we had instead to reduce the differences between them. These new trends lead to the establishment of a third set up with increasingly low and constant differences in CD in the order of 5% CD.

Third set up

In this third set up, the significant gain (p<5%) on the collar girth (CG) was observed with dose 30% CD resulted in a significantly improved mineral nutrition (p<5%) (Breure, 1982) throughout the juvenile stage. This parameter is considered an excellent indicator of vegetative growth during the young age, and is also a good indicator of future crop production (IRHO, 1988).

The applied of organic matter is usually essential for a real improvement in tropical soil fertility (Berger, 1996; Briggs et Twomlow, 2002). Therefore it enables the reduction of the ability to lower aluminium toxicity, the availability of minerals for the plant and especially its ability to exchange cations which varies between 5 to 10 times more than that of some poor clay such as kaolinite.

Concerning plant height (HT), the optimum vegetative growth was also at 30% of CD attesting the efficiency of nutrition at this dosage characterized by progressive mineralization of organic matter (Dupe, 1998) during the stage nursery of plants. The effects of the other doses (35% CD without minerals and 35% CD with 186 g of mineral), although showing relatively high levels, were not significantly (p<5%) different, showing thus that an excess of organic matter is not necessarily essential to a significant performance. As noted with mineral fertilizers, the phenomenon of luxury consumption may also occur in organic fertilization which can lead to asphyxiation of the roots.

Conclusion

- For the first test, the best dose was 20% CD for some variables while the highest dose of 35% of CD could not turn to shine better for all variables. Accordingly, neither the above-mentioned doses cannot be accepted.
- In the second test, the composite minerals were applied in combination with a CD at very high doses. Dose 50% seemed to be the best but, over time, there has been trend reversal in favor of the mineral fertilizer. It was not possible to select the optimal dose.

The use of CD incorporated with soil at nursery stage, with or without mineral fertilizers, is a useful method in cases where farms (oil palm ones) coexist with the practice of cattle-raising.

- In the third test, the results observed highlight the reliability of the optimal dose of CD, obtained as a result of three different test of varying doses. This optimal dose which is 30% of the weight of soil of nursery pots (that is 7.5 kg for a 25 kg pot) is obtained from annex (1) to (4).

The development of a scale of organic and mineral fertilizer for plants at the juvenile stage of palm tree is an important preliminary step of technical routes of that crop. Indeed, the totally organic rational fertilization of the palm tree at the nursery is possible in the absence of any mineral fertilizers for farmers who practice animal husbandry in association with the palm tree.

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Table 1 : Doses of cow dung apply (CD : Bn (0, 1, 2 and 3)) and mineral fertilizers (N, P, K et Mg) for the choice of optimal doses at the nursery stage of oil palm.

SET UP 1	SET UP 2	SET UP 3
Doses of CD : 0, 20, 25, 35% by weight of soil	Doses of CD: 0 ; 25, 50 and 75% By weight of soil	Doses of CD : 0, 25, 30 and 35% By weight of soil
B0 : 0 % of CD	B2E0: 50 % of CD and 0 % of fertilizer	B2E0: 30 % CD and 0 % fertilizer
B1: 20 % of CD	B2E1: 50 % of CD and 1/3 of 186 g of composite fertilizer N, P, K and Mg of formula 3.3.2.1.	B2E1: 30 % of CD and 1/3 of 186 g of composite fertilizer N, P, K and Mg of formula 3.3.2.1.
B2 : 25 % of CD	B2E2: 50 % of CD and ½ of 186 g of composite fertilizer N, P, K and Mg of formula 3.3.2.1.	B2E2: 30 % of CD and ½ of 186 g composite fertilizer N, P, K and Mg of formula 3.3.2.1.
B3 : 35 % of CD	B2E3: 50 % of CD and 186 g of composite fertilizer N, P, K and Mg of formula 3.3.2.1.	B2E3: 30% of CD and 186 g of composite fertilizer N, P, K and Mg of formula 3.3.2.1.

Table 2: Evolution of components (LL4, CG in m; R1 and R2 in kg; MB, MR and ML in l) of growth of seedlings (8 months) of oil palm according to doses of cow dung (first set up).

Cow dung (% weight)	LL4	CG	R1	R2	MB	MR	ML
0	0.27 c	0.24 c	0.01 c	0.17	0.05 c	0.04 c	0.08 d
8	0.36 b	0.29 b	0.17 b	0.19	0.10 b	0.07 b	0.21 c
20	0.44 a	0.32 ab	0.22 a	0.20	0.14 a	0.09 b	0.30 b
35	0.46 a	0.36 a	0.26 a	0.21	0.15 a	0.12 a	0.35 a
Test-F	27.32 **	9.97 *	20.83 **	0.62 ns	20.18 **	37.07 **	72.78 **
S.D.	5.80	5.55	5.33	6.63	35.35	18.23	48.37
CV (%)	14.90	18.00	28.30	33.40	32.30	23.20	20.50

LL4: Length of leaf 4
a, b, c, d : homogeneous groups
MB : Water in the bulb
S.D. : standard deviation
ML: Stock of water in the leaves CG: collar girth
R(1 and 2) : Primary and secondary roots
** : signification at 1%
CV (%) : coefficient of variation.
* : signification at the threshold of 5%
HR : Water in the rachis

Table 3: Comparison of treatments effects CD combined with fertilizers on longest leaf surface ($10^{-2}m^2$), vigor index and DWL (10^{-2}kg) after counting at the end of nursery.

Treatments	Longest leaf surface (LLS)			Vigor index (IV)			DWL
CD X fertilizer	16 weeks	18 weeks	20 weeks	16 weeks	18 weeks	20 weeks	20 weeks
B0E0	0,98a	1,21 a	1,36 a	1,50 a	1,83 a	2,00 a	1,12 a
B0E1	1,16 ab	1,47 b	1,71 b	1,60 a	1,99 ab	2,22 ab	1,83 ab
B0E2	1,28 b	1,47 b	1,76 b	1,68 a	2,03 b	2,23 ab	1,89 ab
B0E3	1,00 a	1,30 ab	1,57 ab	1,59 a	1,96 ab	2,15 a	1,56 b
B1E0	1,10 a	1,45 ab	1,58 a	1,70 a	2,05 ab	2,23 ab	1,71 a
B1E1	1,26 b	1,45 ab	1,76 ab	1,69 a	2,00 a	2,22 ab	1,68 a
B1E2	1,16 ab	1,42 ab	1,84 b	1,63 a	2,03 a	2,22 ab	1,82 ab
B1E3	1,01a	1,32 a	1,59 a	1,62 a	1,95 a	2,14 a	1,59 a
B2E0	**1,32 b**	**1,64 b**	**1,98 c**	1,67 a	1,98 a	2,20 a	**2,03 c**
B2E1	1,17 ab	1,43 a	1,83 b	1,64 a	1,99 a	2,20 a	1,83 ab
B2E2	1,10 a	1,46 ab	1,75 ab	1,59 a	1,98 a	2,17 a	1,61 a
B2E3	1,07 a	1,38 a	1,65 a	1,55 a	1,89 a	2,08 a	1,46 a
B3E0	1,05 a	1,37 a	1,55 ab	1,64 a	1,94 a	2,13 a	1,49 a
B3E1	1,04 a	1,27 a	1,51 a	1,55 a	1,90 a	2,08 a	1,49 a
B3E2	1,09 a	1,45 ab	1,77 b	1,55 a	1,94 a	2,13 a	1,69 ab
B3E3	0,96 a	1,30 a	1,46 a	1,58 a	1,91 a	2,07 a	1,25 a

B: dry cow dung.

E: composite fertilizers (urea, super phosphate single or triple, potassium chloride and kieserite),

B (0, 1, 2, 3): respectively 0, 25, 50, 75 % by weight of soil.

E(0,1,2,3): respectively by weight of (N P K Mg = 3321) corresponding to 186 g of fertilizers) 1/3, 1/2 et 1 by plant at nursery.

DWL = dry weight leaves

Table 4: Classification by homogeneous variable groups of growth measured on CD and mineral fertilizers during nursery.

Traitements (Bouse x Engrais)	Hauteur (m)	Circonférence au collet (m)	Plus longue feuille (m)	Indice de vigueur
B0E0	0,63 a	0,14 a	0,48 a	2,83 a
B0E1	0,69 abc	0,15 abc	0,52 abc	2,90 abc
B0E2	0,66 ab	0,15 abc	0,50 ab	2,85 abc
B0E3	0,76 abc	0,16 abcd	0,54 abc	2,96 abc
B1E0	0,75 abc	0,16 abcd	0,55 abc	3,00 bcd
B1E1	0,78 abc	0,17 abcd	0,58 abc	3,06 cd
B1E2	0,79 abc	0,18 bcd	0,59 abc	3,07 cd
B1E3	0,73 abc	0,17 abcd	0,55 abc	3,00 bcd
B2E0	**0,80 bc**	**0,18 bcd**	**0,60 abc**	**3,08 cd**
B2E1	0,73 abc	0,17 abcd	0,54 abc	3,02 cd
B2E2	0,70 abc	0,16 abcd	0,52 abc	2,95 abcd
B2E3	0,72 abc	0,17 abcd	0,54 abc	3,00 bcd
B3E0	**0,81 bc**	**0,18 bcd**	**0,61 bc**	**3,10 d**
B3E1	0,80 bc	0,18 bcd	0,59 abc	3,08 cd
B3E2	0,73 abc	0,17 abcd	0,55 abc	3,02 cd
B3E3	**0,85 c**	**0,18 d**	**0,65 c**	**3,14 d**
B4E0	0,81 bc	0,18 cd	0,61 bc	3,09 d
B4E1	0,79 abc	0,17 abcd	0,58 abc	3,03 cd
B4E2	0,73 abc	0,17 abcd	0,55 abc	3,03 cd
B4E3	0,77 abc	0,17 abcd	0,58 abc	3,08 cd

B(0,1,2,3,4): respectively by weight 0, 25, 30, 35 et 40 % of CD.

E(0,1,2,3): respectively by weight (N,P,K, Mg : 3.3.2.1) corresponding to 186 g by nursery 25 kg pot.

"a b c d" : homogeneous groups at p < 5%.

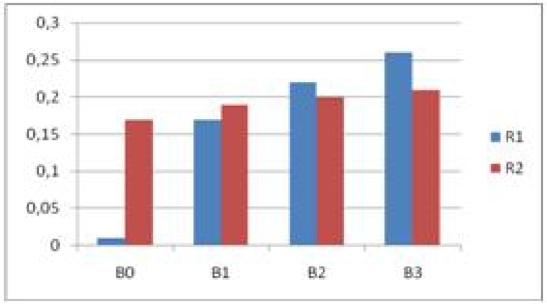


Figure 1: Variation of the dry weight (kg) of primary (R1) and secondary (R2) roots according to doses of cow dung (BO, B1, B2 et B3) under young seedlings of oil palm: (Nursery of set up 1).

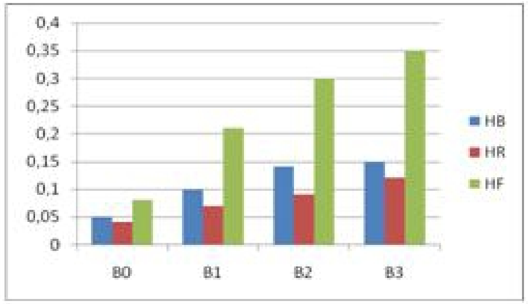


Figure 2: Variation of water content (liters) of the bulb (HB), of the roots (MR) and leaves (ML) according to doses of cow dung under seedlings of oil palm: (Nursery of set up 1).

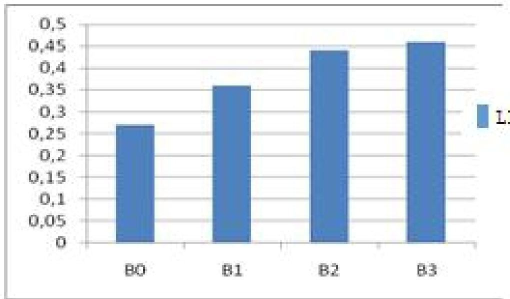


Figure 3: Increase of the length of leaf 4 (LL4) of young seedlings of oil palm according to the dose of CD; (Nursery: Set up 1).

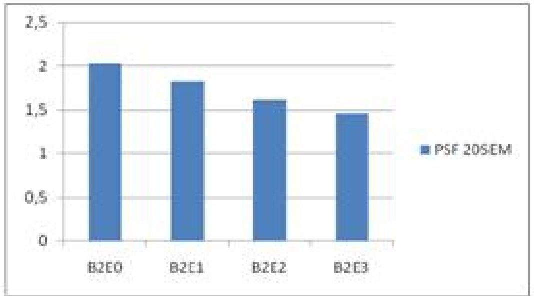
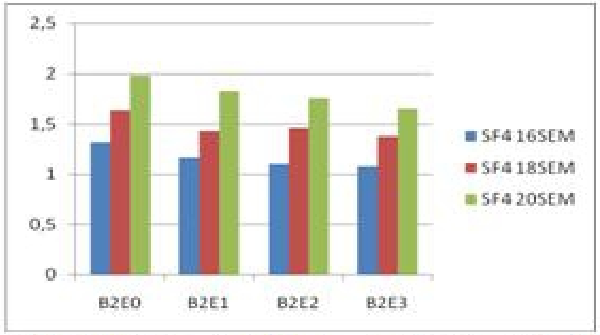


Figure 4: Effect of different treatments on the dry weight (DWL) of leaves of seedlings at the juvenile stage, 20 weeks après replanting of germinated seeds; (Nursery of set up 2).



LF4FFFigure 5 : Evolution of the surface of leaf 4 (LLS) at 16, 18 and 24 weeks of seedlings of oil palm according to variable doses of cow dung added to variable doses of mineral fertilizers (N, P, K et Mg) ; (Nursery of

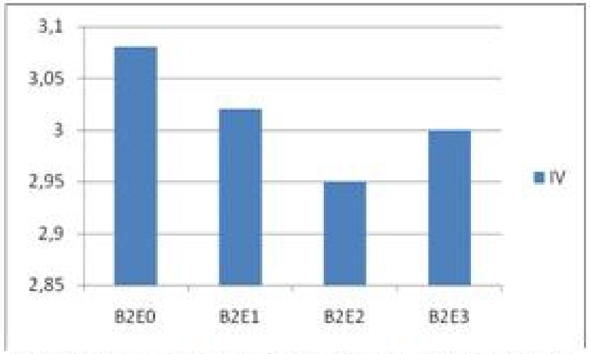


Figure 6: Comparison of vigor indexes (VI) of seedlings of oil palm according to Variable doses of mineral fertilizers with constant dose of cow dung; (Nursery of set up 3).

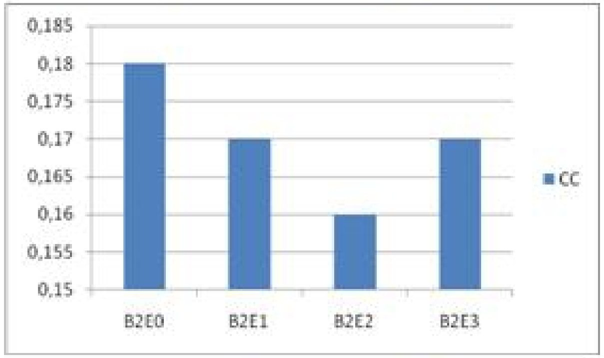


Figure 7: Variability of the collar girth (CG) of seedlings of oil palm under the effect of constant dose of cow dung and variable doses of mineral fertilizers; (Nursery of set up 3).

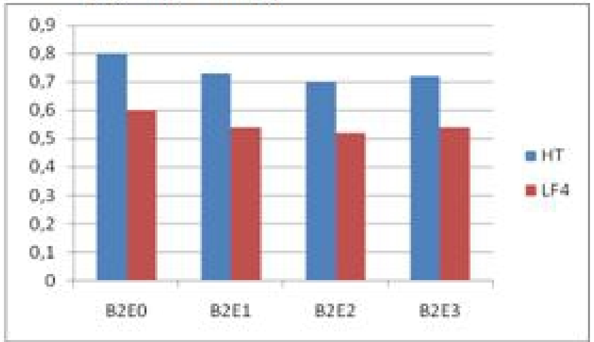


Figure 8: Effects of the constant dose of cow dung (B2) and variable doses of mineral fertilizers on the height of seedling (HT) and the length of leaf 4 (LL4) of seedlings of oil palm ; (Nursery of set up 3).

Annex

Apparent density of the soil: D = W/V; where W is the weight of the soil obtained by direct weighting, and V, volume of the bag.

Apparent density of CD: d = w/V; where w is the weight of CD collected and storedand weighted directly.

Apparent density of the mixture: D'= (x*D + y*d) where x and y representing the ratios of soil and CD.

Weight of the mixture: W' = D'/V.

Vigor index: $VI = \log [C^2 / (4 \times Pi \times \sqrt{(D^2/ (4+LL4^2))})]$, where the collar girth is CG; length of leaf number 4 of the plant is LL4; D is diameter of the circle and Pi: 3.14.

Vigor index simplified: $VI = \log [C^2 \times LL4 / 4 \times Pi]$.