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Effects of Increasing Doses of NPK Fertilizer (17-17-17) on Nursery Initiation of *Pennisetum purpureum* Schum. (Poaceae) and Organic Tillage on Degraded Soil, Kisangani

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Abstract. Our study was initiated to evaluate the effects of increasing doses of NPK fertilizer (17-17-17) on nursery initiation of *Pennisetum purpureum* shoots and organic tillage on degraded soil in Kisangani.

The crop was installed under actual conditions in Kisangani on an area of 42.9 m^2. The agronomic parameters observed included the rate of resprouting of cuttings, the tillering index of shoots, the soil-root interface under the emerging grass stand and the dynamics of earthworms.

We adopted a randomized complete block design, following the provisions related to agroforestry experiments.

The results showed that organo-mineral fertilization used in the nursery beds, under the conditions of our trials, clearly influenced rhizogenesis and the metabolic activity of the vegetative apparatus of the nursery sprouts. This suggests that a residual effect related to the nutrient content of the plant material would accompany the transplanting of well-fed nursery offshoots into the field. And the application of NPK, under the conditions of use defined during our experiments, clearly influenced the root density nor the soil-root interface.

Key words: NPK, organic matter, *Pennisetum purpureum*, rhizogenesis, degraded soil, fertilizers

Introduction

The establishment of grass-legume fallows is a prerequisite for a mini-mechanization of peasant agriculture throughout the tropical world (Comino & Druetta, 2010; Roldan *et al*., 2005; Xiao *et al*., 2012).

The notorious infertility and near degradation of cultivated land on the outskirts of villages and urban hinterlands, especially in developing countries, creates a major obstacle to agricultural development (Pyame *et al*., 2021b; Phillips *et al*., 2012; Carter, 2005).

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Pennisetum purpureum is a tall perennial grass with high forage production potential that is used to form rich pastures and agroforestry fallows (Pyame, 2015; Ntamwira, 2021). However, its establishment by cuttings in the field requires frequent replanting, which is too costly, particularly during dry spells that have become frequent in the middle of the rainy season (Pyame *et al*., 2021a).

Would nursery multiplication of propagation material on substrates with low doses of fertilizer lead to more abundant and less costly production of shoots and stump fragments, to the point of interfering with soil fertility and biological tillage?

The multiplication of *Pennisetum purpureum* propagation materials in a nursery, on a substrate with increasing doses of NPK fertilizer, would induce, in the same order, a production of shoots, stump fragments and a dynamics of earthworms more important on degraded soil.

Materials and Methods

Environment

Geographic location and experimental period

Our experimental field was established in Kisangani, capital of the province of Tshopo, in the Democratic Republic of Congo, more precisely at PK12 on the Banalia axis, in the annex commune or Collectivity-Secteur of Lubuya-Bera, at the agroforestry station of the Faculty of Management of Renewable Natural Resources (FGRNR) of the University of Kisangani.

The geographical coordinates of the city of Kisangani are as follows Latitude: 0° 11' North; Longitude: 25° 1' East; Altitude: 390 to 410 m with an average of 400 m. The city of Kisangani is located in the central basin straddling the Congo River. Its relief is a set of plateaus interspersed with river beds and streams (Kenga, 2012).

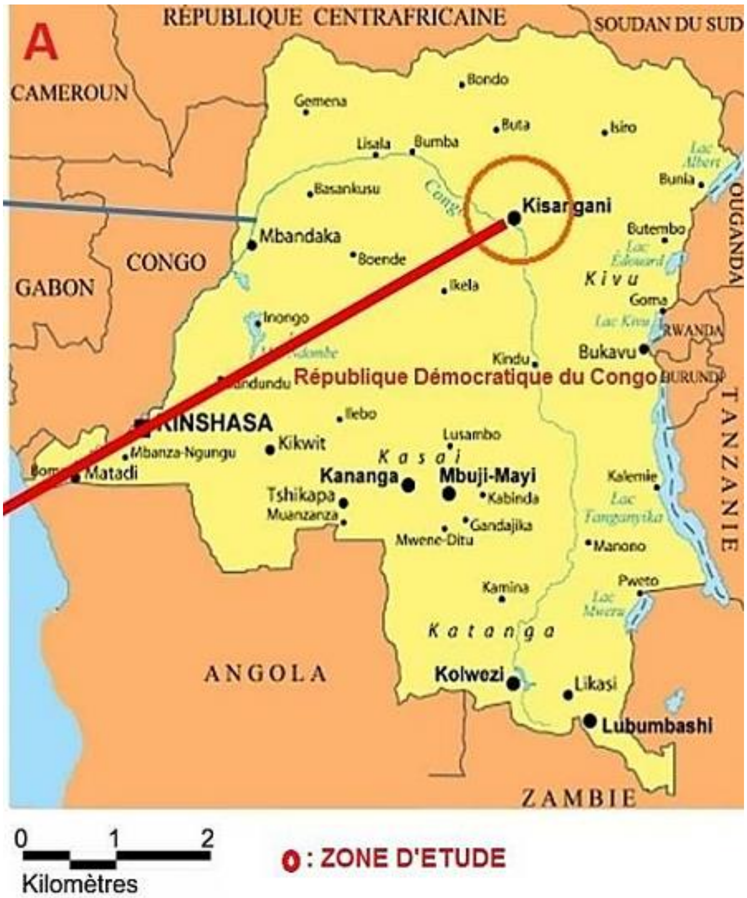

Figure 1: Map of the location of the study area

The city of Kisangani has an equatorial climate, characterized by high heat and humidity. This makes Kisangani an environment where total hydrolysis predominates.

According to the classification of KOPPEN, this climate is of the Af type characterized by a monthly height of precipitations of the driest month superior to 60mm and an annual average temperature superior or equal to 24°C. The average relative humidity is very high all year round and is between 80 and 88%, the annual average being 84%. The insolation is 1972 hours.

Annual rainfall is over 1800mm and is divided into two seasons, one very rainy (mid-August to mid-December) and the other rainy month (mid-March to mid-June).

Soil of the experimental site and previous crop

The soil of our experimental site, as with all the soils around Kisangani, is ferralitic (Pyame, 2015). The previous crop was cassava and soybean. We could also observe some grasses such as *Cyperus sp* (Cyperaceae), *Croton hirtus* (Euphorbiaceae), *Comelina diffusa* (Comelinaceae), *Euphorbia heterophilla* (Euphorbiaceae), *Panicum maximum* (Poaceae), *Spermacos latifolia* (Rubiaceae), *Pueraria phaseolides* (Fabaceae), and *Cynodon dactylon* (Poaceae), which was predominant.

Materials

This work required the use of a material as varied as diversified. We used, in turn, biological, technical and fertilizing materials, which we describe below.

Biological material

The biological material used was cuttings of *Pennisetum purpureum.*

Figure 2: *Pennisetum purpureum* in the experimental field (© Utshudi, 2021)

Farming and other materials

A long machete for clearing the land, a watering can for occasional watering, 50 cm stakes and string for delimiting the plot, a hoe for minimum plowing and weeding, a decameter for measuring the surface area of the plots, a 5-liter basin for transporting and spreading fertilizer, six plastic buckets for transporting and spreading manure, three nylon ropes for sowing and, finally, one motorcycle for transportation to the research station.

Laboratory equipment

A variety of equipment was used in the laboratory: pressure balance, suspension balance, copecky cylinder, beakers, aluminum trays, porcelain crucibles, oven and desiccator.

Fertilizing equipment

Restoring fertility to degraded soils involves not only the application of crop residues to the surface, but also the return of nutrients exported by crops and the application of humus amendments to replenish humus (CIAT-TSBF, 2009). Thus, we used a raw mulch-compost made of fans of the previous crop, NPK 17/17/17 fertilizer and farmyard manure (pig droppings).

Experimental Setup

We adopted a complete randomized block design, following the provisions pertaining to agroforestry experiments, according to Pyame (2015). The sketch below shows the schematic of this design.

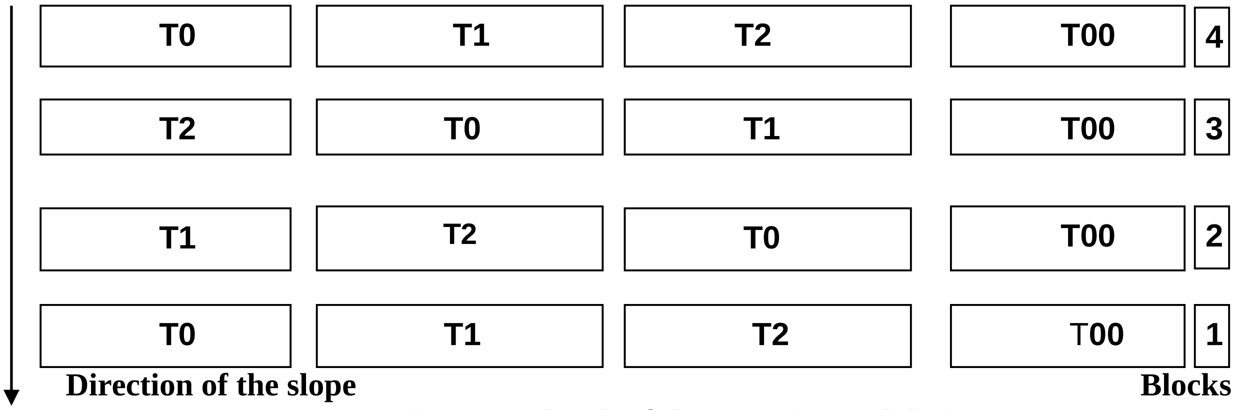

Figure 3: Sketch of the experimental design

Legend: T00 = Current planting practice, direct cuttings in the field; T0 = production of shoots in the nursery without any additional input; T1 = production of shoots in the nursery with a single basal application of NPK fertilizer with organic matter; T2 = production of shoots in the nursery with two basal applications of NPK fertilizer with organic matter

Methodological Approach of the Trial

The methodological approach includes the following operations carried out successively: clearing and cleaning of the land, ploughing, delimitation of the experimental plots, cutting of *Pennisetum purpureum*, planting of the cuttings in the beds, watering of the treatment plots (except for the absolute control), application of the improvement treatments, maintenance work and collection of data according to the experimental parameters selected.

Preparatory work for the trial

This consists of the delimitation of the site, its complete clearing and cleaning, the cutting, transport and cutting of the *Pennisetum purpureum*. Sap-filled stems, 3 m high, were carefully cut with a machete; cuttings with 3 internodes were then stored in the shade for 24 hours.

Planting of cuttings and application of ameliorative inputs

Pennisetum purpureum cuttings were planted in 6 m x 1.2 m beds, with 2 cuttings in each 30 cm equally spaced pots. 5g of NPK + 500g of manure were applied per m^2. The dose of NPK on 10.000 m^2 (1ha) will be 5.10^3 x 10+4 kg = 50 kg for T1 and the double dose is 100 kg for T2.

Maintenance work in the nursery

They include 2 weedings and regular watering once every 3 days on the different treatments, except for the absolute control representing the current practice of planting *Pennisetum purpureum* in the region.

Data collection according to the selected parameters

Rate of emergence per cutting planted in the nursery and per 2-cuttings pellet. The number of emerged cuttings was collected, at the end of 15 days after planting, from 2 circumscribed samples (yield square) on the treatment plot considered, at the level of each block. The result was expressed as an emergence rate based on all planted cuttings and on the basis of the 2-cutting pockets planted.

Number of secondary shoots per plant (tillers). This index, which provides information on the multiplication coefficient of the propagation material, and thus the regenerative capacity of the grass cuttings, was measured by counting the number of branches on each of the planted cuttings included in the yield square in two plot samples.

Earthworm counts in the crop profile. The field survey and all the organizational work that constituted the beginning of this laborious phase of our study were conducted according to Lavelle (1973). The samples were taken in accordance with the manual sorting method recommended by the Tropical Soil Biology and Fertility (TSBF) program. This method has been used in turn by Lavelle (1983), Lavelle *et al*. (1995) and Mulotwa *et al*. (2001).

Eight cultivation profiles, two for each treatment, were laid out, each with a monolith (block of soil) of 25 cm x 25 cm x 30 cm, equivalent to approximately 30 kg of soil, at its center. The monolith was subdivided into four quadrants, the results of which were counted separately. Three main 10 cm soil slices were distinguished on each quadrant to facilitate the subsequent manual sorting.

The monolith was thus explored from top to bottom by passing successively through 3 strata namely (1) 0 to 10 cm, (2) 10 to 20 cm and (3) 20 to 30 cm. The earthworms isolated in each stratum were counted and the respective values carefully recorded, thus giving the spatial structure of colonization of the cultural profile. From this, a total per quadrant, per soil stratum, and then per m^2 of surface area was produced at the end of each operation.

Apparent density and spatial structure of the rooting of the agro system. This investigation, carried out concomitantly with the apparent density of the soil, made it possible to identify the root density profile, i.e., the evolution of root density in the depth of the soil (Pyame, 2015). A Coppécky cylinder of standard volume (100 cc) was used to sample under the grass stand 4 successive soil strata (5 cm) invaded by roots, thus realizing a cultural profile of 20 cm on 2 of the 4 replicate plots, for each treatment.

Immediately brought back to the laboratory, the successive weighing of the samples contained in cylinders of known weight (PO) led, at the end of the drying in the oven, to the obtaining of constant weights (PC). Subsequently, the contents of the cylinders are gently pulverized to collect all the roots. These will then be weighed (RMD in g/100cc) and measured with a batten and the values summed (Root Length Density in cm/cm3).

Statistical treatment of the data. The data of the study were processed by means of the Excel program and "R" software, using in turn the analysis of variance and Tukey's tests for the significance of the differences between the evaluated treatments.

Results

We present alternately (1) the average recovery rates of cuttings and the average tillering indices of shoots obtained at the strategic multiplication phase, in nursery, of the *Pennisetum purpureum* propagation material, (2) the parameters defining the soil-root interface, namely the total porosity and the root density (Root Mass Density and Root Length Density) for the treatments confronted, and finally (3) the dynamics of earthworms under the grass cover of the flower beds

Average Recovery Rates and Average Tillering Indices of Transplanted Shoots

These results are presented in Figures 4, 5 and 6 below.

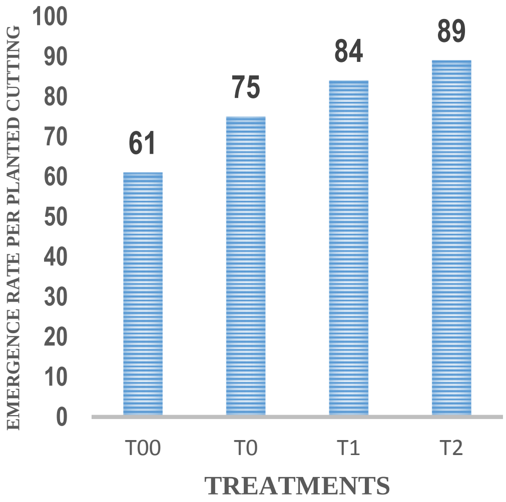

Figure 4: Emergence rate of cuttings per stake per park

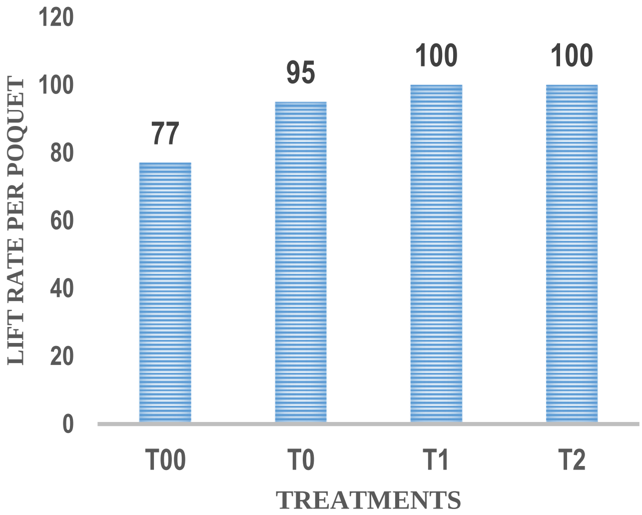

Figure 5: Emergence rate of 2 cuttings per stake

Examination of the results in Figures 4 and 5 shows that the rates of regrowth of shoots are significantly higher in the three nursery treatments (T0, T1 and T2) than in the absolute control (T00), which bypasses nursery work and uses simple cuttings without roots and leaves as propagation material.

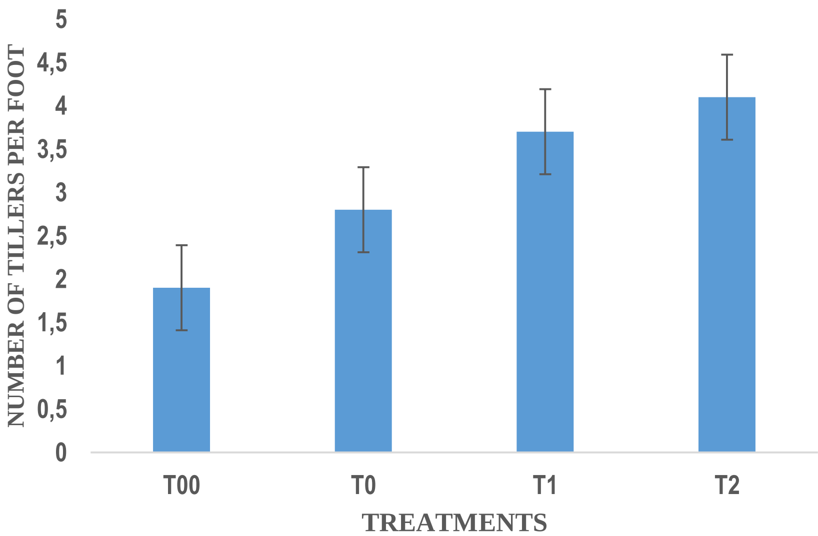

Figure 6: Number of tillers per plant of *Pennisetum purpureum* according to treatments

On examination of the results in Figure 6, it is clear that the tillering indices of the shoots are clearly higher in the three treatments using nursery work (T_0, T_1 and T_2) than in the absolute control (T_{00}) bypassing the latter. Moreover, there is a clear superposition of the curves relating to the organo-mineral fertilization of the rejection beds, the value of the p-index leading to a significant difference between these 3 treatments.

It can be said that the organo-mineral fertilization used in the transplant beds, under the conditions of our trials, had a clear influence on rhizogenesis and metabolic activity of the vegetative system after transplantation to the field.

This suggests that there is a residual effect of the nutrient content of the plant material after transplanting the well-fed offsets into the field.

Parameters Defining the Soil-Root Interface

Bulk density and porosity

These results are presented in Figures 7 and 8 below.

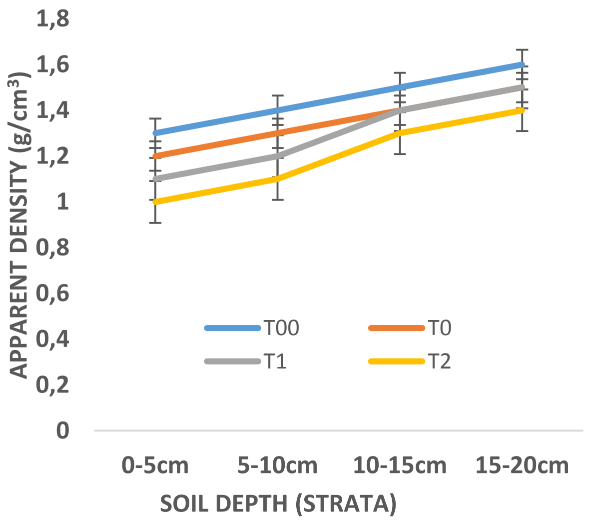

Figure 7: Bulk density in g/cm^3

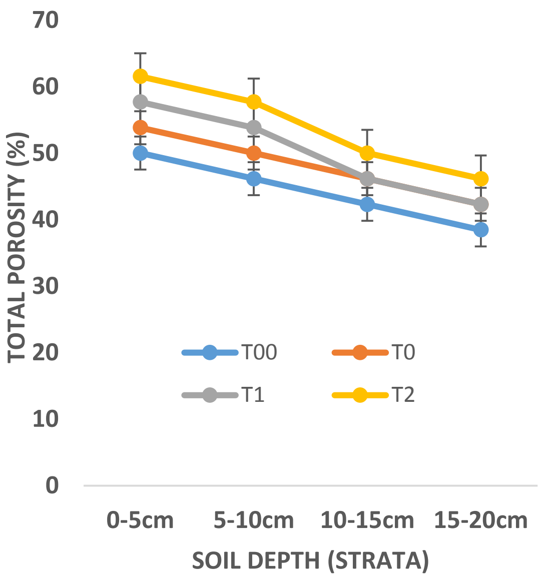

Figure 8: Total porosity (%)

Examination of the results in Figures 7 and 8 shows that the diagrams relating to the different treatments are clearly distinct, but supplant each other more or less proportionally to the doses of hormones and NPK fertilizers used in the organo-mineral fertilization, the absolute control referring to the current practice of establishing *Pennisetum purpureum* by direct cuttings being the least effective treatment

Root density (RMD) and soil-root interface (RLD)

These results are presented in Figures 8 and 9 below.

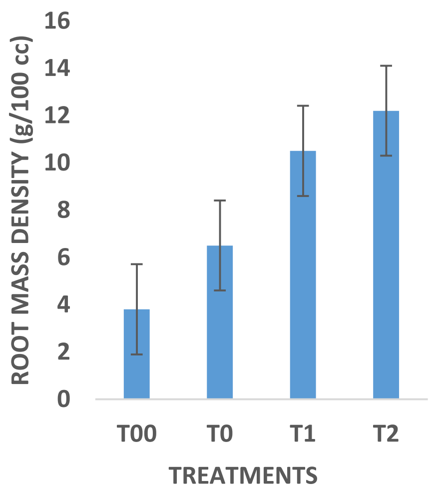

Figure 9: Root density in g/100 cc

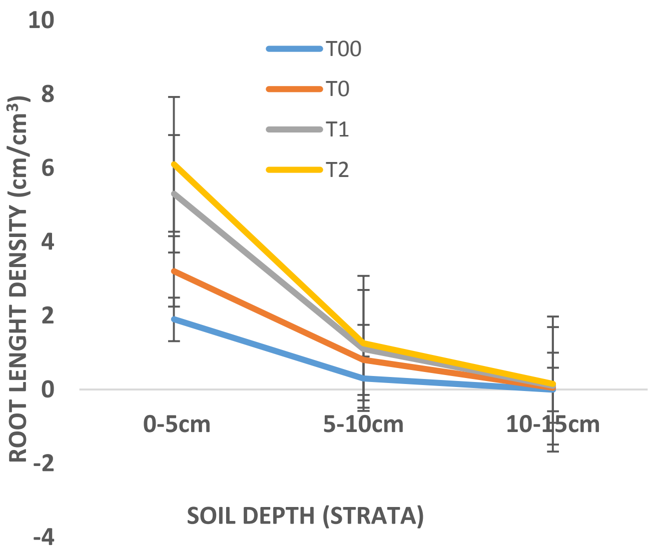

Figure 10: Soil-root interface in cm/cm^3

Examination of the results in Figures 9 and 10 shows that the diagrams for the different treatments developed in the nursery are significantly higher than those for the absolute control, which refers to the current practice of establishing *Pennisetum purpureum* by direct cuttings, and is therefore considered the least effective.

In addition, the plots for the treatments using increasing doses of NPK 17-17-17 fertilizer (0, 50 and 100 kg/ha) in combination with a constant dose of pig manure (5t/ha) in the nursery beds stood out.

The value of the discrimination index of the treatments "p", in the analysis of variance led to a significant difference between these treatments. This clearly shows that the organo-mineral fertilization, under the conditions of use defined during our experiments, did not clearly influence the average height of the plants and the average number of leaves per plant.

Dynamics of earthworms under grassy cover in the beds

These results are presented in Figure 11 below.

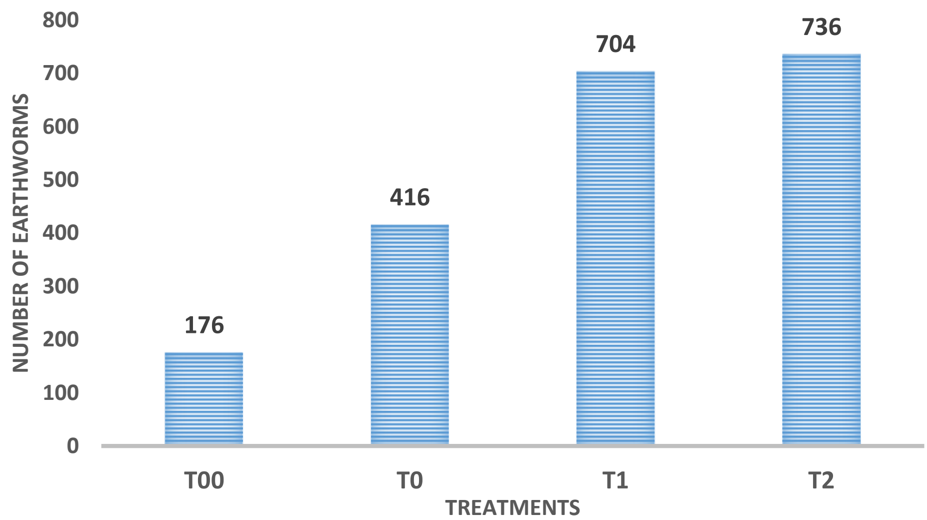

Figure 11: Number of earthworms under grassy cover in flower beds

Examination of the results in figure 10 shows that the plots for the different nursery treatments are significantly higher than the absolute control, which is the least efficient way of establishing *Pennisetum purpureum* by direct cuttings.

In addition, the plots for the treatments using increasing doses of NPK 17-17-17 fertilizer (0, 50 and 100kg/ha) in combination with a constant dose of pig manure (5t/ha) in the nursery beds stood out.

The value of the treatment discrimination index "p", at the analysis of variance, led to a highly significant difference between these treatments. This clearly shows that organomineral fertilization, under the conditions of use defined in our experiments, had a clear influence on the average height of the plants and the average number of leaves per plant, in proportion to the doses of fertilizer used.

Discussion

The concern raised at the beginning of this research was to know if the multiplication in nursery of the propagation material, on substrates provided with increasing microdoses of NPK 17-17-17 fertilizer could induce a more abundant and less expensive production of shoots and splinters. The aim was to verify to what extent this could favorably interfere with the rhizospheric soil ecology (increased fertility) through biological tillage by roots and earthworms, whose dynamics are thus improved.

Average Recovery Rates and Average Tillering Indices of Transplanted Shoots

It is necessary to say, at the end of this work, that the application, in nursery, of increasing doses of fertilizer NPK 17-17-17 coupled with the manure of pigs has very clearly influenced the rate of resumption of the shoots to the transplantation in front of the practice of direct cutting in open field (95% against 80% and 93% against 60%)

The difference in emergence rate for two cuttings per stake between these four treatments was not statistically significant at the 5% threshold (ANOVA: F = 1.374; ddl = 3; p-value = 0.298), whereas the emergence rate for one cutting per stake between these four treatments was statistically significant at the 5% threshold (ANOVA: F = 5.611; ddl = 3; p-value = 0.0122*). Figures 12 and 13 show the values of emergence rate for one cutting per potting and that of two cuttings per potting for each of the treatments studied.

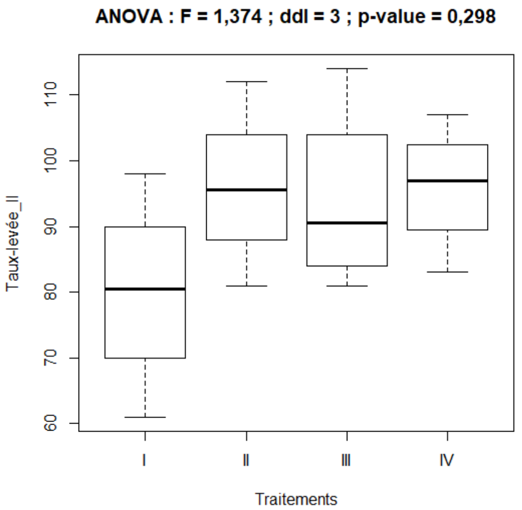

Figure 12: Emergence rate of 2 cuttings per cluster

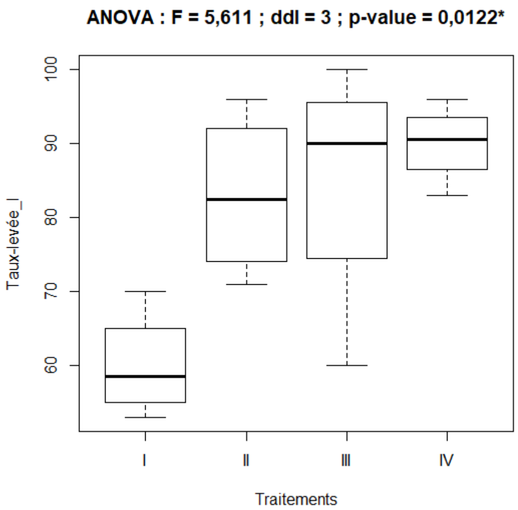

Figure 13: Emergence rate of 1 cutting per cluster

Similarly, the tillering index increased with the use of auxins (17.5 and 35 kg/ha) and fertilizer (50 kg and 100 kg with 5 t manure per hectare), i.e. 1.9%, 2.8%, 3.7% and 4% respectively for direct cutting in the field without watering and the non-use of auxins + manure in the nursery. The difference in number of tillers between these four treatments was not statistically significant at the 5% level (ANOVA: F = 3.166; ddl = 3; p-value = 0.0639).

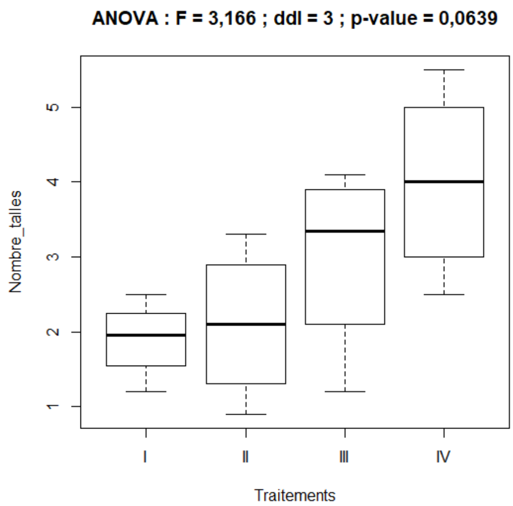

Figure 14: Number of tillers per plant of *Pennisetum purpureum* according to treatments

Similar research using fertilizer inputs under grass cover has been undertaken by different authors:

(1) a high level of microbial activity and assimilable P was found to be directly proportional to the density of the hairy root system and to the amount of inputs regularly accumulated on the surface under conservative cultivation (Salinas-Garcia *et al.*, 2001; Dos Santos *et al.*, 2011);

(2) perennial grass hedges, especially grass hedges, as well as micro-pools play an effective role in reducing water, ion and soil losses under cultivation and soil humus richness (Comino & Druetta, 2010; Huang *et al.*, 2010; Xiao *et al.*, 2012).

Parameters Defining the Soil-Root Interface (Porosity, Root Density, Earthworm Numbers)

With respect to the parameters defining the soil-root interface (porosity, root density, earthworm numbers, in general, the nursery-developed treatments clearly outperform the T00, the local practice of direct field planting of *Pennisetum purpureum* cuttings. There is therefore a clear advantage to pre-production of cuttings in the nursery, with or without the addition of chemical inputs.

On the other hand, the diagrams of the treatments using the application of increasing doses of NPK fertilizer (50 Kg and 100 Kg/ha) to the nursery beds, combined with a constant dose of pig manure (5 t/ha), did not stand out among them.

The value of the discrimination index of the treatments "p", in the analysis of variance led to a non-significant difference between the treatments "increasing doses of NPK fertilizer 17-17-17". This clearly shows that chemical fertilizer applications, under the conditions of use defined in our experiments, did not influence either the parameters defining the soil-root interface or the dynamics (numbers) of earthworms.

Indeed, research on the application of increasing doses of NPK fertilizer on the green carpet of *Pennisetum purpureum* associated with leguminous plants has been very successful on the yields of integrated food crops, namely rice, maize and banana (Pyame, 2015; Ntamwira, 2021).

It has also been established that crops and grasslands managed under grass cover develop a high root density and a higher hydromineral demand creating conditions for high soil exploration (Yang *et al.*, 2004, Yang *et al.*, 2005; Herold *et al.*, 2014), thus proving to be more productive than those in conventional agriculture (De Carvalho *et al.*, 2012).

Concerning Total Porosity and Density of Earthworms under Grass Cover

A variable density of earthworms is reported by several authors comparing zero tillage to conventional tillage: 80 vs. 49 (Norgrove *et al.*, 2011), 81 vs. 52 (Xu *et al.*, 2013), 319 vs. 61 (Errouissi *et al.*, 2011), 572 vs. 280 (Schmidt *et al.*, 2003).

The densities of earthworms found in our nursery-developed treatments range from 176 to 736 individuals per m2. This is within the range above but does not reach the values found by PYAME (2015) who worked on a distinctly clay soil and 2-year grass-legume fallows. Indeed, the latter reported densities ranging from 580 to 1700 individuals/m2/30 cm, respectively for the slash-and-burn crop and the Plate crop under Green Carpet.

The difference in the number of earthworms between these four treatments is highly significant at the 5% threshold (ANOVA: F = 10.32; ddl = 3; p-value = 0.00121*).

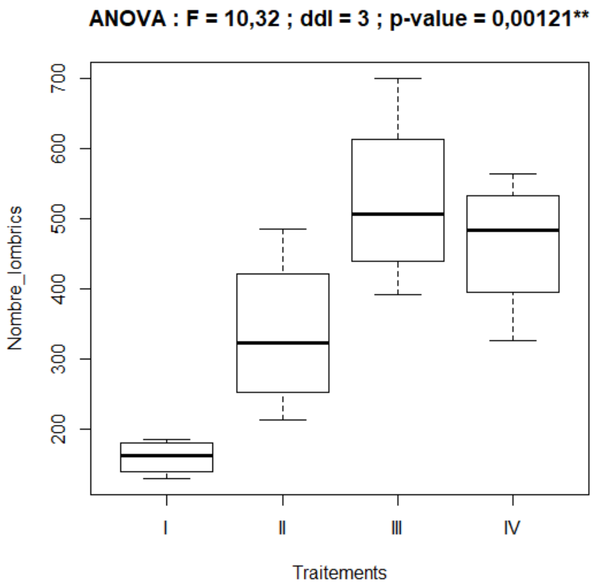

Figure 15: Number of earthworms under grass cover according to treatments

The high densities of earthworms recorded in this experiment are attributed to the favorable climatic conditions, the methodological care (manual exploration-disintegration of soil monoliths) but also and especially to the high production of recyclable inputs (Pietola & Alakuku, 2005) and root exudations emanating from perennial roots (Phillips *et al.*, 2012) under the *Pennisetum purpureum* grass fallow.

Thus, balanced application of organic inputs from grass stands stimulates earthworm activity, thereby influencing aggregate dynamics and macroporosity (Eriksen-Hamel *et al.*, 2009; Jouquet *et al.*, 2012).

Porosity in these surface strata is related to the aggregating activity of roots / edaphic bioagents (soil shear potential) including earthworms (Sileshi & Mafongoya, 2006).

Conclusion

The purpose of this study was to experimentally measure the resprouting rate of cuttings, shoot tillering index, soil-root interface under the emerging grass stand, and earthworm dynamics in response to increasing microdoses of NPK 17-17-17 chemical fertilizer applied in the nursery.

As for the recovery rates and tillering coefficient, the tillering indices of the shoots are significantly higher on the three treatments using nursery work (T0, T1 and T2) than on the absolute control (T00) bypassing the latter. Moreover, there is a clear superposition of the diagrams relative to the organo-mineral fertilization of the rejection beds, the value of the index "p" leading to a significant difference between these 3 treatments. It can be said that the organo-mineral fertilization used in the transplant beds, under the conditions of our trials, clearly influenced rhizogenesis and the metabolic activity of the vegetative apparatus of the nursery sprouts. This suggests that a residual effect related to the nutrient content of the plant material would accompany the transplantation of well-fed nursery offshoots into the field.

Regarding the total porosity and root density, it should be noted that the value of the discrimination index of the treatments "p", in the analysis of variance led to a non-significant difference between these treatments. This clearly shows that the application of the fertilizer NPK 17-17-17, under the conditions of use defined during our experiments, did not clearly influence the root density nor the soil-root interface.

In the context of earthworm dynamics, the value of the discrimination index of the treatments "p", in the analysis of variance, did not lead to a significant difference between these treatments. This clearly shows that the application of increasing doses of the chemical fertilizer NPK 17-17-17, under the conditions of use defined in our experimental set-up, did not affect the number of earthworms under the grassy cover of the strip-plant at all.

We particularly suggest that this research be continued in longer trials, with a wider range of fertilizer materials and a wider range of species, including food crops, cover crops and legumes.

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