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Research Article

Comparative Study of the Agronomic Effect of Compost from Faecal Sludge Scum and Faecal Sludge Ash on Vegetable Crops in the Sangalkam Area of Senegal: Case of Onion (*Allium cepa*)

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Abstract

Valorisation of faecal sludge is an option that is increasingly being explored in the context of faecal sludge management. This study is part of that process and tests the effect of compost from faecal sludge and ash from faecal sludge incineration on onions. Thus, faecal sludge ash and scum compost were characterised and their nitrogen content was used to calculate the doses to be applied. The Fischer block design was set up with 6 treatments organised in 4 replications, with three factors such as compost dose, compost+ash dose and chemical fertiliser; 24 plots of 3 m² each. The monitoring parameters were leaf height, number of leaves, collar diameter, average fruit weight, fruit diameter and yield. The results show that the normal dose of 16.66 t/ha is better than the compost+ash composition and chemical fertiliser on onion in terms of leaf height, number of leaves and crown diameter, with 45.42 cm; 6.85; 1.027 cm respectively. The best yield was obtained with the normal dose of compost with 42.5 t/ha.

Keywords: *Agronomic value, sewage sludge, scum compost, sewage sludge ash, onion.*

Introduction

According to Agassounon., *et al.*, (2012) cited by Dovonou, *et al.*, (2017), in Africa, 344 million people did not have access to an improved source of drinking water in 2010 and 222 million defecated in the open air. To combat the practice of open-air defecation, many low- and middle-income countries have invested in the development of on-site sanitation facilities. In these countries, an estimated 2.1 to 2.6 billion people now use on-site sanitation systems, which produce tons of untreated faecal sludge (FS) every day (Strande, *et al.*, 2014). Following the example of the Developing Countries (DCs), the State of Senegal has, since 2000, set up the Periurban areas sanitation programme of Dakar (Programme d'Assainissement de Quartier Périurbains de Dakar (PAQPUD)), which is a component of the Water in a long-term programme (Programme Eau à Long Terme (PLT)), to overcome the glaring deficit of sanitation infrastructures. When septic tanks and latrines are full, the sludge extracted from them is largely discharged without any treatment into open drainage channels, agricultural fields, wastelands or surface waters.

According to Tayler, (2018) agricultural application of FS was once a common practice

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in Europe and the US, and is still practised in many low- and lower-middle-income countries. The interest in using this sludge is related to its value as an organic and calcium amendment. They help to maintain or improve soil structure, biological activity and control soil acidity (Chaussod and Nomain, 1996 cited by Pisson, 2000). In addition, human excreta are very rich in nitrogen and other nutrients necessary for plant growth. The humus formed by the decomposition of faeces also contains trace elements that reduce the susceptibility of plants to pests and diseases (Sonko, 2008).

Indeed, the spreading of raw sludge is at the origin of the contamination of crops by pathogens but also of soils by toxic substances which are, according to Lô, (2020) copper, nickel, chromium, zinc, iron, lead, mercury and cadmium.

The national organization of sanitation of Senegal or the Office National de l'Assainissement du Sénégal (ONAS), in partnership with the Bill and Melinda GATES Foundation, is building on its programme of the structuration of the market of faecal sludge (Programme de Structuration du Marché de Boues de Vidange (PSMBV)) by developing an innovative technology for treating wastewater. However, this FS recovery process generates ash that should also be managed and recovered with the least possible negative impact on the environment. However, during combustion, organic components are mineralised (Demeyer, *et al.*, 2001). Given their richness in mineral elements useful for plants, agricultural spreading seems to be the most attractive way to valorise them.

In Senegal, horticulture is one of the most dynamic sectors in the agricultural sector due to the permanence of its activities (all year round), the number of practitioners, the diversity of species cultivated, but also the geographical location of the cultivation area as well as the financial benefits for the main producers (Gueye, 2018). L'horticulture contribue largement à l'approvisionnement en légumes des villes. It is therefore a key element of food security in growing cities and a factor in regulating unemployment (Fall and Fall, 2001). However, because of the reduction in soil fertility due to intensive farming, producers, in order to optimise yields, resort to the massive use of chemical inputs, including fertilisers, which are loaded with nutritive elements for the plant but also with toxic elements that persist in the soil. Thus, to improve the fertility of these degraded soils, the search for other means of fertilisation is becoming an absolute necessity.

In view of all these concerns, this study proposes to evaluate the agronomic effect of Faecal sludge (FS) scum compost and the effect of FS ash on onion. Specifically, it consists of characterising the sewage sludge ash and scum compost used, knowing the effect of the ash and scum compost on the growth and development parameters of cabbage and onion plants during the vegetative cycle and measuring the production parameters and calculating the yield of the two crops.

Materials and Methods

Study Area

The work was carried out at the Sangalkam research station of the Senegalese institute of Agricultural research, (Institut Sénégalais des Recherches Agricoles (ISRA)) in the Dakar region of Senegal (Figure 1).

Biophysical Setting (Climate, Geomorphology, Vegetation Cover)

Like the whole of the Niayes area, the commune of Sangalkam is located in a Sahelian climate zone, where the maritime trade winds blow for three to six months and bring coolness (Faye, 2010).

The relief of the district of Sangalkam, like that of the entire Niayes area, is relatively homogeneous. According to Faye, (2010). Many lowlands are located in villages such as Diacksao, Niaga, Dény Biram Ndao North and South, Gorom I etc. (Figure 1).

The vegetation of the Municipality is essentially characterized by swampy grasslands, shrub savannahs, wooded savannahs, shrub steppes and cultivated areas (Faye, 2010).

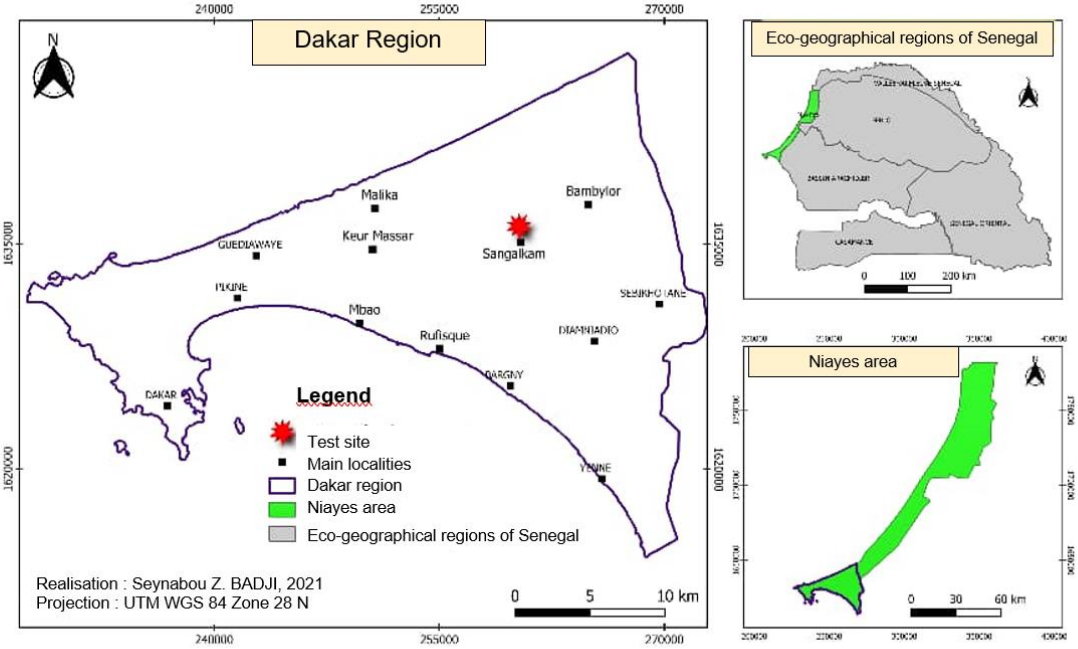

Figure 1: Location map of the study area

Faecal Sludge Ash

The ash used as fertilizer material was obtained from the combustion process of dried faecal sludge with the Omniprocessor (OP) (Figure 2) installed at the Niayes Faecal Sludge Treatment Plant (STBV).

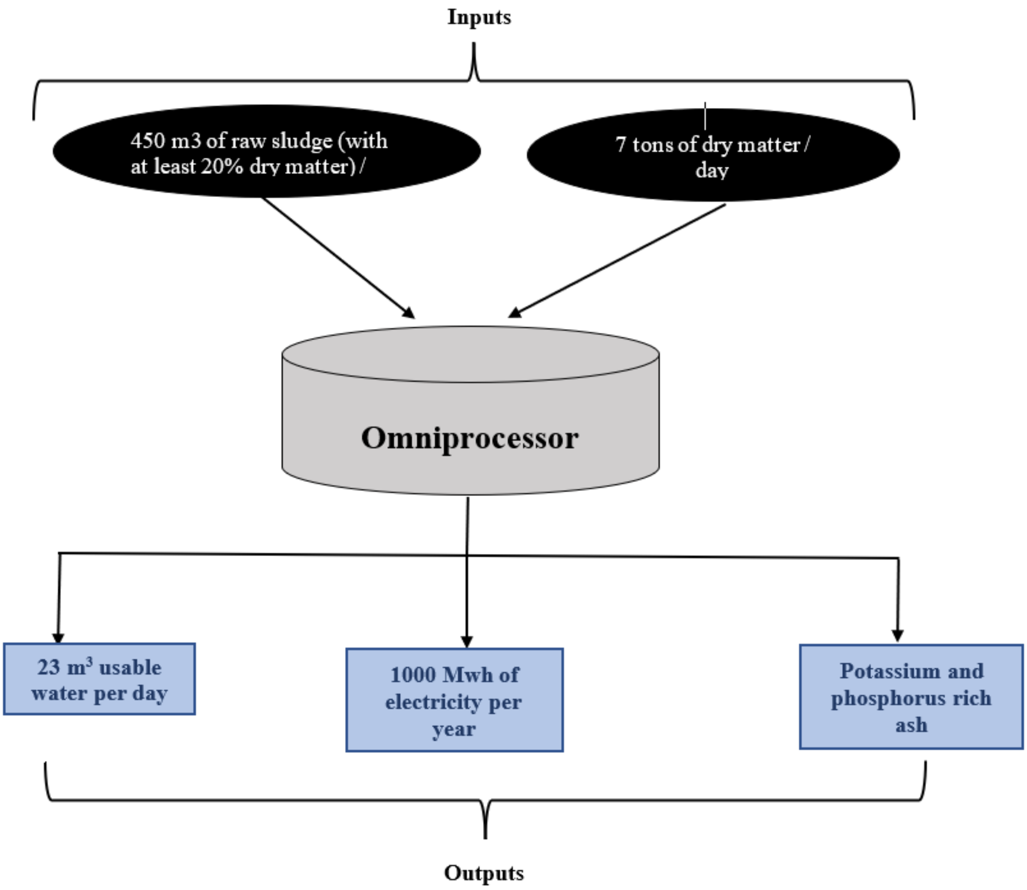

Figure 2: Omniprocessor (OP) waste treatment process (BADJI, 2020)

The Omniprocessor (OP) shown in Figure 3 is a sewage sludge combustion technology that generates pathogen-free commercial by-products, including distilled water, ash and electricity. The hot water produced by the pathogen-free system can be used for on-site applications or in nearby facilities (slaughterhouses, hospitals, etc.) or cooled and used in construction, agriculture, industry, transportation etc.

Figure 3: Omniprocessor

The ash is rich in phosphorus and potassium (Figure 4) and can be used as fertiliser or in the manufacture of bricks for construction (Faye, 2014).

Figure 4: FS ash from the omniprocessor

Sewage Sludge Compost

The compost used (Figure 5) as a fertiliser in the trials is a compost produced from the scum of domestic sewage sludge collected at the Niayes wastewater treatment plant. It is produced by a decantation process that allows the recovery of the floating solid part, which is then composted until complete decomposition. This is sludge collected from household septic tanks. Its heavy metal content is very low, making it suitable for agricultural use, unlike sewage sludge, much of which comes from industrial installations.

Figure 5: Sludge scum compost

Chemical Fertiliser NPK

The chemical fertiliser NPK 10-10-20 (Figure 6), was used in this study to compare its effectiveness with that of sewage sludge ash and compost in plant nutrition.

Figure 6: Chemical fertilizer NPK 10-10-20

The Parameters Studied

Compost Dry Matter (DM)

The dry matter of the compost is determined according to ISO 665: 2000. The principle of the method is as follows. A sample of the compost in an empty bottle of mass M was placed in the oven to be dried at 105°C. If M1 is the mass of the flask and the sample before drying and M2 the mass after drying, the dry mass or MS is determined by the following formula

$$\mathrm{MS} = \frac{\mathrm{M_2 - M}}{\mathrm{M_1 - M}} \times 100 \quad (1)$$

Organic Matter (OM) in Compost

The organic matter of the compost is also determined according to ISO 665:2000. The principle is that of loss on ignition, which consists of placing a compost sample of mass M2, previously dried at 105°C, in a flask of mass M in an oven at 550°C. The sample is left in the oven for 4 hours. The sample is then removed from the oven, cooled and weighed. M3 is the mass obtained. The OM is calculated from the following formula:

$$\mathrm{OM} = \frac{\mathrm{M_2 - M_3}}{\mathrm{M_2 - M}} \times 100 \quad (2)$$

Field Trials

The choice of onion as an experimental crop is based mainly on its high phosphorus (P) need.

Preparing the Plants in the Nursery

The field trials are preceded by a period of preparation of the plants in the nursery, which is two (2) months long. The location of the nursery was chosen according to the following criteria: flat plot, proximity to a watering point, protection (wind, temperature differences and pests). Watering with tap water was done daily with watering cans. Once the plot had been well delimited (12 m2 in area) on the chosen land, the seeds were sown in rows (figure 7) on a layer of organic manure (horse manure) previously spread on the plot.

Figure7: Preparation of onion nursery bed

Experimental Set-Ups

The setup is a Fisher block design (randomized complete set up) with six (06) treatments, organized in four (04) replications, with three (03) doses of compost and ash. This makes a total of twenty-four elementary plots of 3 m² (figure 8). Each elementary plot was ploughed and well levelled in order to have a flat surface called a bed for a homogeneous distribution of watering. Tees were built to delimit the plots.

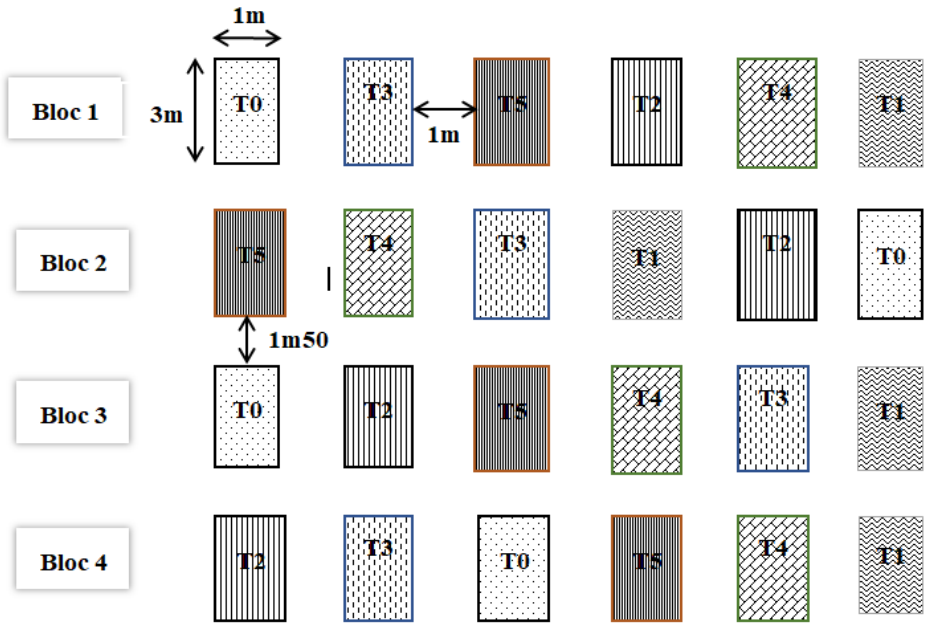

Figure 8: Fisher's experimental block for Onion

Bottom Dressing and Transplanting

On each elementary plot, except for the sample plots, a dose of horse manure determined according to the surface area (2 kg per 1 m²) was applied as a basic manure. The plots were then spaded to allow the organic matter to be buried and pre-irrigated to moisten the soil and thus accelerate the degradation of this organic matter. The transplanting of onion plants previously prepared in the nursery was done in November. Six (06) rows of twenty-seven (27) plants each were transplanted, the spacing between the rows is 15 to 20 cm and between the plants, 10 to 15 cm. The number of rows and the spacing between the transplanted plants varies according to the species and the technical standards of the CDH.

Crop Fertilisation

Compost and ash rates are calculated to meet N, P and K requirements in order to determine the optimum rate for the crop. In this case this element is phosphorus for onions (Table 1).

Table 1: NPK content and requirement

	N	P	K
Fertilizer contents			
Compost (en %)	7,18	10,24	1,3
Fertilizers (kg/ha)	10	10	20
Ashes (g/kg)	-	58,85	5,48
Need for culture			
Onions (en Kg)	100	200	200

The doses of fertilizers applied (compost, ash, chemical fertilizer) are calculated from the following formulas:

T0 (no fertilizer)

T1 = Normal dose of compost (calculated according to the needs of the crop in Annex 1)

T2 = 50% of T1 + 50% of the normal dose of ash (calculated with the same method as T1)

T3 = T1 + 25% of T1 = higher than normal dose

T4 = T1 – 25% of T1 = Lower than normal dose

T5 = Normal dose of chemical fertiliser (calculated with the same method as T1)

The doses obtained calculated on the basis of the onion's NPK requirements (Table 1) are as follows:

- **(T0)** Growing ithout fertiliser (sample) ;
- **(T1)** Scum compost at 16.66 t/ha ;
- **(T2)** Scum compost 7.66 t/ha + FS ash at 18.23 t/ha ;
- **(T3)** Scum compost at 20,83 t/ha ;
- **(T4)** Scum compost at 12,5 t/ha ;
- **(T5)** NPK fertiliser at 1 t/ha.

The calculated fertiliser quantities were divided by three in order to carry out cover fertilisation at twenty (20), forty-four (44) and sixty-two (62) days after transplanting.

Maintenance of Transplanted Plots

Irrigation was carried out daily using a connection to the water pumping borehole installed inside the station.

Phytosanitary treatments using manual backpack and pressure-maintained sprayers were applied to control crop pests. These treatments are applied fifty-two (52) and fifty-nine (59) days after transplanting. Weeding is done manually or mechanically, to stop the development of weeds. Every week, a hoeing is carried out on the surface of the soil at a depth of a few centimetres to allow aeration of the soil and good water infiltration.

Growth Parameters

To assess the agronomic value of the compost and ash, measurements are made on growth and development parameters.

On each elementary plot and outside the border lines, twelve (12) plants were selected. This choice is based on the number of plants in the plot. Measurements on growth variables were made on the number of leaves, leaf length, diameter at the crown of the plants and nitrogen content.

A Greenseeker is used to measure nitrogen content, a tape measure to measure leaf length and width, and a caliper for collar diameter. The number of leaves per plant is obtained by manual counting.

Production Parameters

After harvest, onion production was determined for each elementary plot as well as individual fruit weight and diameter.

The variables are taken from twelve (12) randomly selected samples from the plot production.
The production parameters are the diameter taken with a caliper (Figure 9) and the weight taken with a Kern & Sohn electronic scale.

Figure 9: Measurement of fruit diameter

Data Processing and Analysis

The measurements obtained were used to evaluate the influence of compost and ash on the onion. The objective of the statistical analyses is to synthesise the results and compare them in order to better appreciate the effect of compost and ash on the evaluated parameters. The data thus obtained were first classified in the Excel spreadsheet of the Microsoft office 2016 software and then subjected to a test of variance (ANOVA) using the XLSTAT software.

Results

Effects of the Different Amendments on the Vegetative Parameters of the Onion

The Average Height of Onion Plants at 45 Days after Planting (DAP)

Figure 10 below shows the average heights of onion plants according to the treatments.

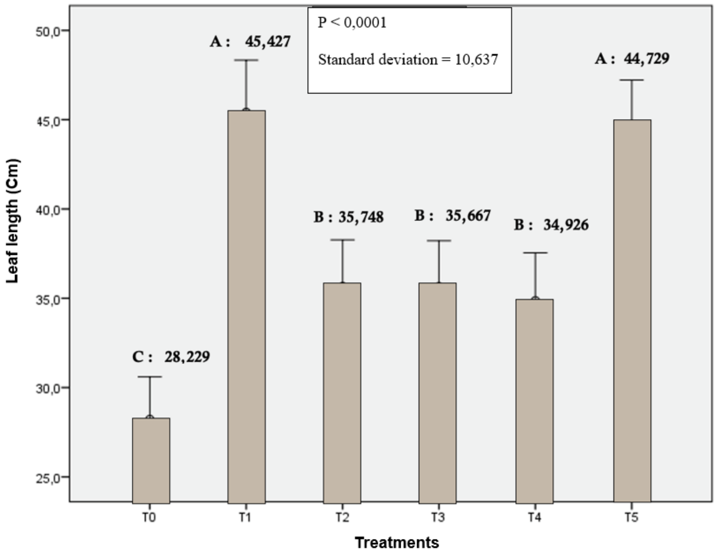

Figure 10: Plant height according to treatments

The analysis of variance shows a significant difference between the means (P < 1/1000). In treatments T1 (Citrus compost at 16.66 t/ha) and T5 (NPK fertiliser at 1 t/ha) the highest mean length values were found, respectively 45.42 cm and 44.72 cm, which is about 2 times higher than those observed in the sample plants, T0, which gave the lowest values at 28.22 cm. The incorporation of different fertilisers into the soil influences the growth of onion plants.

The Number of Onion Leaves on the 35th Day (DAT)

The analysis of variance showed that the treatments are significantly different (Pr < 0.010). On the other hand, the inter-treatment analysis (Turkey test) shows that there is a significant difference between treatments T1 and T5 (fertiliser 10-10-20), but no significant difference between treatments T3, T2, T0 and T4. The results (figure 11) indicate that the test of variance of the number of leaves of the onion at day 35 is highly significant, which explains why there is a difference in the average number of leaves between the treatments studied.

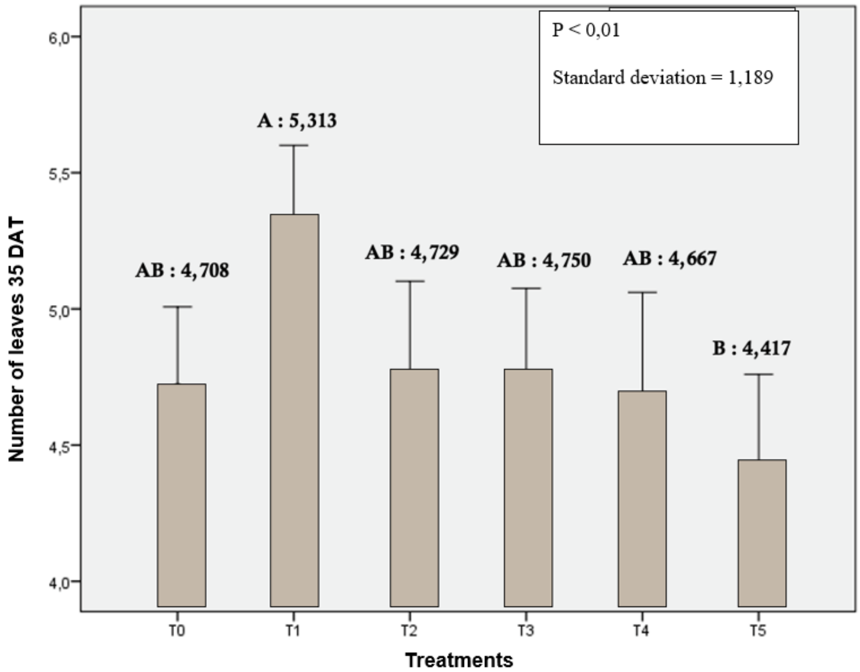

Figure 11: Number of leaves according to the treatments at 35 DAT

The Number of Onion Leaves on the 45th Days after Transplanting (DAT)

The results of the test of variance of the number of leaves at day 45 indicate that there is a highly significant difference between the treatments studied ($P < 0.0001$) (Figure 12).

The figure shows that treatment T1 with compost gave the highest mean leaf number of 6.854 and treatment T0 (Control) the lowest mean leaf number of 5.208. This explains why compost contributes to the increase in leaf number of the plants. This explains why compost contributes to the improvement in leaf number yield.

The figure shows that treatment T1 with compost gave the highest average number of leaves at 6.854 and treatment T0 (Control) the lowest average number of leaves at 5.208. This explains why compost contributes to the improvement in leaf number yield.

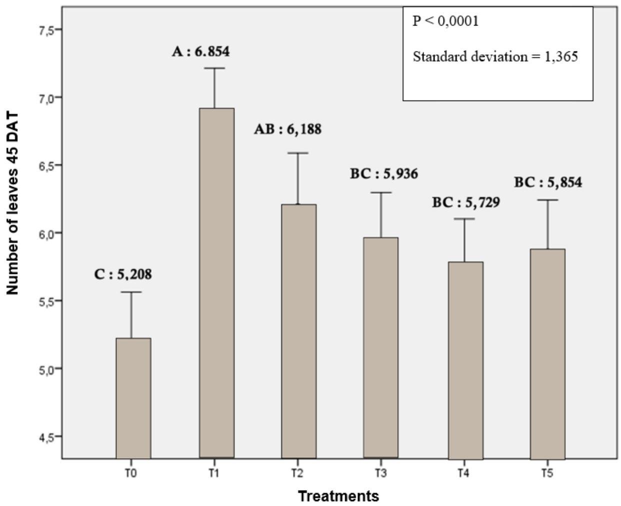

Figure 1: Number of leaves at 45 days after transplanting (DAT)

Diameter at the Neck of the Onion

The test on the analysis of variance of the average diameter at the crown carried out indicates a highly significant difference between the treatments studied, i.e. $P < 0.0001$ (figure 13).

Treatments T1 (compost) and T5 (fertilizer 10-10-20) gave the highest mean crown diameter values, respectively 1.027 cm and 0.869 cm.

The T0 treatment has the lowest mean of 0.537 cm. The inter-treatment test (Turkey test) with groups A, AB, BC, CD and D reveals that there is a significant difference between T1 and T0, T2, T3, T4, between T5 and T0, T2. However, only the T2 treatment (compost+ash) does not differ significantly from T0.

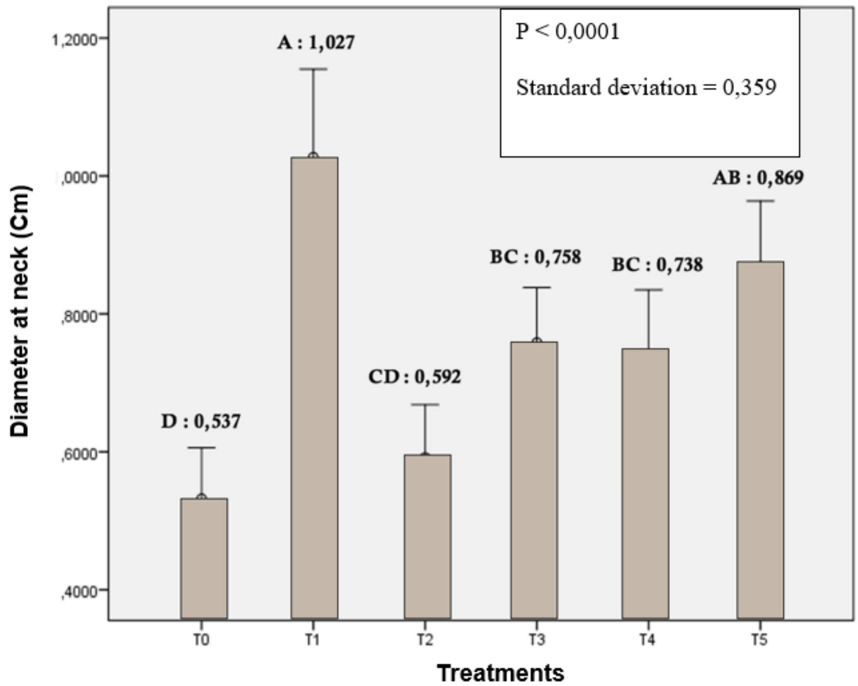

Figure 23: Diameter of the collar according to the treatments

Effect of Different Amendments on Onion Production Parameters

Average Onion Fruit Weights by Treatment

Figure 14 below shows the mean harvested fruit weights (in grams) by treatment. The variance test shows that there is a significant difference between the means according to the treatments ($P < 0.0001$).

Treatment T5 (chemical fertiliser) gave the highest value, 163.524 g, which represents the average weight of a fruit, followed by treatment T1 (normal dose compost) with 133.286 g. However, there was no significant difference between treatments T1 and treatments T2 (compost+ash), T3 (lower dose compost) and T4 (higher dose compost), which yielded 112.78 g, 112.823 and 108.030 g respectively. The lowest production was obtained with treatment T0 (sample).

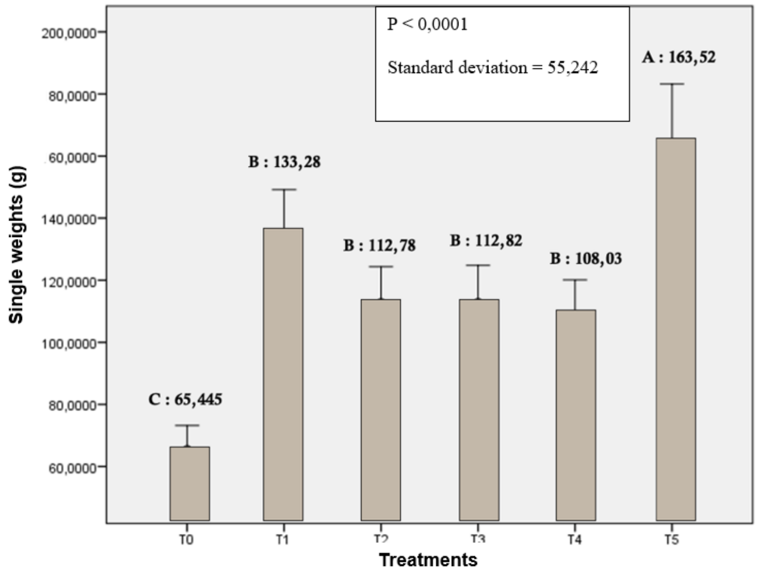

Figure 3: Average fruit weight according to treatments

Average Diameters of Onion Fruits

The means of the diameters according to the treatments are shown in Figure 15. The variance test shows significant differences (P < 0.0001).

The largest average diameter of 7.165 cm was recorded by treatment T5, followed by treatment T1 with 6.454 cm. No significant differences were observed between treatments T1 (6.454 cm) and treatments T2 (6.121 cm), T3 (6.227 cm) and T4 (5.976 cm). The fruits in the T0 control treatment had the smallest diameters.

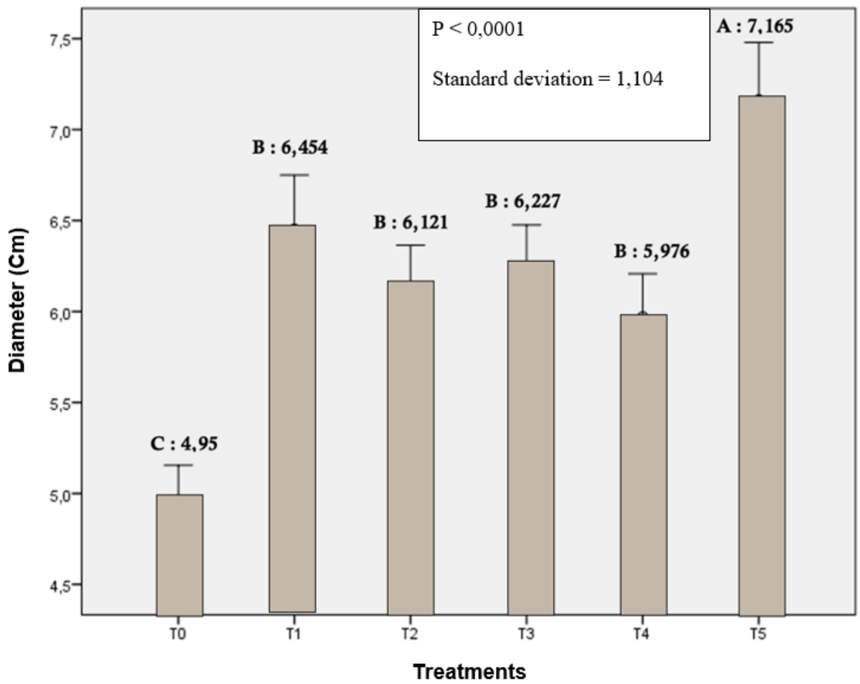

Figure 4: Average fruit diameter

Onion Yield

The results of the variance test show that the treatments are significantly different (P = 0.046). Figure 16 shows the average yields of onions according to the treatments.

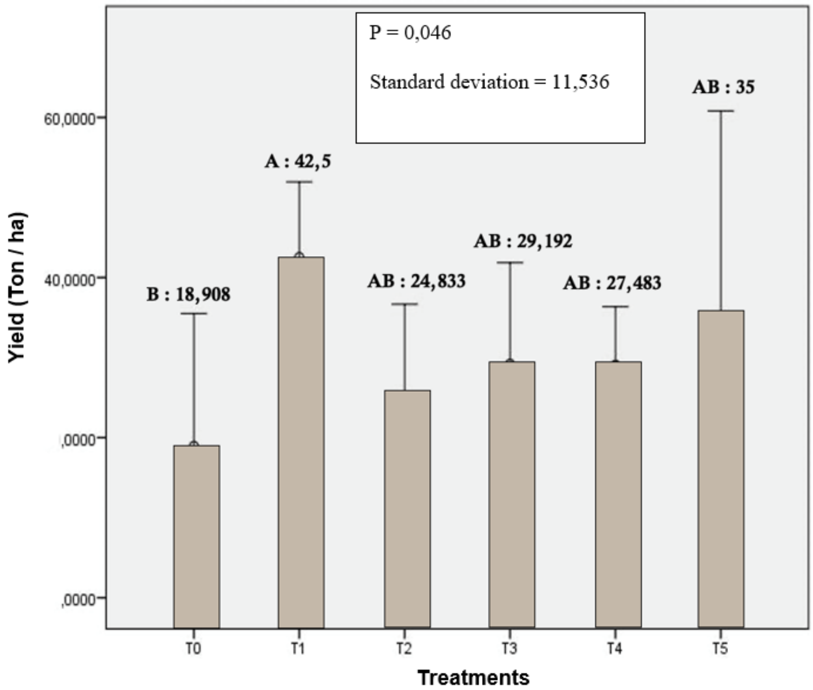

Figure 5: Onion yields in relation to treatments

The results show that T1 gives the highest yield values with an average of 42.5 t/ha. This value is higher than the average yield of T0 which is 18.9 t/ha but is not significantly different from treatments T2 (24.83 t/ha), T3 (29.19 t/ha) and T5 (35 t/ha).

Table 2: Production yields according to treatments

Applied Treatments	Yields in t/ha
T0 (no fertiliser)	18,90
T1 (normale dose of compost)	42,5
T2 (compost+ash)	24,83
T3 (higher dose of compost)	29,19
T4 (lower dose of compost)	27,48
T5 (chemical fertiliser)	35

Discussion

The quantitative parameters of all treatments are better than those of the control but they differ from each other depending on the parameter and the dose of compost incorporated at the beginning (Mouria, *et al.*, 2016), as well as the dose of ash applied.

The results of the vegetative parameters for onion reveal that treatment T1 (skim compost at 16.66 t/ha) performs better than treatments T3 (skim compost at 20.83 t/ha) and T4 (skim compost at 12.5 t/ha). This could be explained by the fact that the normal dose of compost (treatment T1) induces an optimal development of the onion plants. Furthermore, it contributes better to this development than chemical fertiliser (10-10-20) because the release of nutrients is much slower with compost than with chemical fertiliser. This gives the plants time to take them up. On the other hand, the same amount of compost (T1) is more productive than the composition (compost+ash) with regard to plant growth and leaf development. Indeed, work has shown that plant height growth is largely linked to the availability of nitrogen in the soil (Toundou, *et al.*, 2014). However, the ash contains almost no nitrogen, which means that it does not complete the reduction of the normal compost dose by 50% in the T2 treatment.

These results are interesting in that they confirm those of several authors in the literature such as Lo, *et al.*, (2019); Lessard, (1992); El Fels, (2014); Sawadogo, *et al.*, (2008); Konaté, *et al.*, (2018) according to whom compost has amending properties and improves crop nutrition, growth and yield. Our results also confirm those of Sawadogo, *et al.*, (2008), who showed that the contribution of compost has a beneficial effect on the growth and development of sorghum.

At harvest, the best production in terms of individual fruit weights and diameters is obtained with T5 (chemical fertiliser). In fact, the vegetative cycle of the onion is made up of two periods, one corresponding to development and leaf growth during which nitrogen (N) requirements are paramount and another period of reserve formation (bulbs) where the roles of potash (K) and phosphorus (P) are predominant. Composts from BVs have agronomic potential to meet the nutritional needs of crops, especially for phosphorus (Amorim, J. *et al.*, 2021). Thus chemical fertiliser (10-10-20) would be of great benefit in this second phase of the cycle because of its high phosphorus (P) content compared to compost. This explains why the bulbs harvested from the chemical fertiliser plots are larger than those from all other treatments.

Compared to treatments T2 (compost+ash), T3 (higher dose of compost) and T4 (lower dose of compost), T1 with the normal dose of compost obtained onion bulbs of larger size even though the productions were not significantly different.

From this result it can be said that for onions, compost was more productive than chemical fertiliser. This could be explained by the potassium content. According to Williams and Kafkaf, (1998), Chapagain and Wiesman, (2004) cited by Mpika, (2015) the potassium provided by the chemical fertiliser would contribute to flowering and fruit development.

Work by Mpika, *et al.*, (2015) on three tomato varieties showed that potassium applied at low doses as potassium sulphate increased yield. It was found that the highest yields obtained in the three varieties would require low amounts of potassium made available to them. These results suggest that high potassium inputs had no effect on the yield of the three varieties. By analogy, this could explain why the higher doses of potassium applied by the chemical fertiliser (10-10-20) induced a decrease in yield in favour of the T1 results.

The yield obtained with onion in this study is higher than the optimum yield of PADEN which is 20-35 t/ha corresponding to the yield we obtained with chemical fertiliser (35t/ha). The same trend is observed by Bello, *et al.*, (2012) in their work on onion where the maximum yield was 34 t/ha with an application rate of 450 kg/ha of mineral fertilizer.

Thus, to increase soil productivity and maintain soil health, it is necessary to add organic fertilisers to the soil because according to Alvarez (2005), mineral fertilisers alone cannot maintain soil productivity in the long term due to leaching and degradation of soil properties. The results of De Lucia, *et al.*, (2013) showed an improvement in biomass production due to the influence of compost on the nutritional status of plants.

This study is in line with that of Toundou, *et al.*, (2014) for whom the highest yield was obtained with the Cassia compost treatments without ash 20t/ha but not significantly different from that obtained with the compost with ash.

It should be noted that the compost was better. This could be due to the fact that the compost is richer in phosphorus at 10.24% than in nitrogen at 7.18%.

Conclusion

The objective of this study was to evaluate the effect of BV dross compost and BV ash on onion. To this end, field trials to determine their agronomic efficacy were conducted.

The treatment with the standard dose of compost showed the best results for leaf height (45.42 cm), number of leaves (6.85), crown diameter (1.02 cm) and yield (42.5

t/ha). The results with the chemical fertiliser were significantly different from those obtained with the other treatments for all growth, development and yield parameters.

In view of these results, improving the nitrogen content in the compost should be a crucial point. It would therefore be necessary to co-compost the scum with nitrogen-rich materials. As for the ash, it could not replace the compost because it is almost devoid of organic matter. On the other hand, its application at a rate of 50% of crop requirements is not suitable for soil aeration as it clogs pores and does not facilitate water infiltration. However, taking into account its high proportion of phosphorus (58.85 g/kg) compared to nitrogen (N) and potassium (K), FS ash could be co-composted with nitrogen-rich materials. In addition, it could also be used as a material in the cement industry for construction or as a buffer for acidic soils. It would also be relevant to study the nutrient and Trace Metal Element (TME) content of the fruit after harvest.

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