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DETERMINING THE OPTIMAL DOSE OF SOLID-LIQUID NPK ON MAIZE YIELD

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ABSTRACT

The experiment was conducted at INERA - Mulungu, located 30 km North of Bukavu city on Bukavu Goma Road. This study was conducted from Frebruary to June, 2013 at the Cirhumbi. The objective of the study was to determine the best form of fertilizer allowing a good assimilability of three major elements (N, P, K) for the optimal growth of corn and the determination of the optimal dose of NPK in form. solid or liquid for a good corn yield. The results from this work showed that the vegetative parameters were influenced according to the form of fertilization and the dose with high values in the NPK solid fertilization. Yield parameters also varied by fertilization form and dose level: the number of ears plant^{-1}, the weight of fresh spaths, the weight of dry ears without spars and the grain yield were increased with increasing doses of NPK. The 130 kg dose of NPK significantly increased yield compared to plots fertilized with lower doses or that yielded 4.8 tons ha^{-1} on average.

Thus, the solid form of NPK remained the best form of intake of these three major elements to the corn crop, given the edapho-climatic conditions of the study environment.

(Keys words : Determination, dose, NPK, solid-liquid, yield, maize)

INTRODUCTION

Maize is the first cereal in the DRC after rice, having a huge importance for the food of the Congolese population. Maize is grown in all provinces, but mainly in the provinces of Katanga, Bandundu and two Kasai, which together accounted for 63% of the national production (1,155,720 tonnes in 2007). It plays a crucial role both in terms of food security and in increasing the incomes of farm households in the DRC in general and in South Kivu in particular.

Total maize consumption is still growing in the Democratic Republic of Congo. At the end of the last decade, it knew an average growth rate of 4.1%, whereas production had only increased by 2.8% at the time, the deficit being filled by imports (Anonymous, 1993). Thus, in R.D.C, the importance of the maize deficit is justified by increasing consumption and also by the fact that this foodstuff occupies the first place among imported food products. Currently, Kivu imports large quantities of maize: in 1996 the city of Bukavu imported 170 tons of grain maize (Anonymous, quoted by Mbaya, 1998). Corn is an industrial raw material for food products or not, more and more numerous and diversified. These new uses open up particularly interesting prospects for tropical countries in the process of industrialization.

Indeed, despite the importance of maize in DR Congo, culture presents major challenges. Low soil fertility is one of the plausible limitations to maize productivity. Some studies report a continuing decline in soil fertility, resulting in a steady decline in yields (Musungayi *et al*., 1990).

In the peasant environment, techniques for improving and preserving soil fertility are limited to the use of simple practices such as crop rotation, mulching, application of compost, etc. Generally fallow is very rare.

However, the importance of fertilizers is rising for crop yield increases, which can be doubled or even tripled, and in raising and / or maintaining the level of productivity of cropland (Anonymous , 2003).

According to (Tom, 1992) in the search for a sustainable agricultural system, fertilizers should

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theoretically ensure at least the return to the ground of the quantities of mineral elements removed by the harvest (maintenance fertilization) and also ensure the conservation soil fertility level (bottom fertilization) over the years of cultivation and take into account possible leaching losses.

Corn responds well to nitrogen fertilization, while in the tropics the response to P and K is less pronounced. It is generally applied 88 to 110 kg of N , kg ha $^{-1}$ or even 150 kg ha^{-1}. The special requirement for nitrogen just prior to flowering should be emphasized to allow normal ear formation (Westphal *et al*., 1985). Nitrogen is the main factor in plant growth and crop yield (Anonymous, 1980). Thus, nitrogen is one of the very first factors of production. Nitrogen intake will influence not only the juvenile growth of maize, but also its crude digestible protein content at the end of the season, phosphorus intervenes in the maturation mechanism and will therefore directly influence the dry matter content; potash will lead to ear and grain formation (Anonymous, 2010).

Corn is very fast growing, so fertilizer must be available when the crop needs it. Most of the nutrients are removed during the relatively short period of flowering and ear formation, specifically 10 days before the onset of male flowers until 25-30 days later. During this period, the plant will absorb 70% to 75% of nitrogen and 2/3 of its phosphorus and potash requirements (Oost and Toffoli, 2012).

In order to increase maize production in the region, the rational use of chemical fertilizers is urgent. According to Vanlauwe and Giller (2006) and Giller *et al.* (1998), phosphorus intakes in legumes doubled crop biomass and increased the agronomic efficiency of fertilizers in cereals.

Since liquid fertilizers are used less than solid fertilizers, they have many advantages: they act quickly, thus providing plants with the nutrients they need very quickly and at a precise moment they are absorbed immediately by the plants and contain amino acids that gradually release natural nutrients (N, P, K) that stimulate healthy and regular growth of plants. Liquid fertilizers are very convenient to use and spread evenly in the soil unlike solid fertilizers (Louis, 2011). The different forms and doses of fertilization of NPK would have a different influence on maize yield because they are factors determining the quantity assimilated by the plant and leaching fertilizer elements in the form of mineral fertilizers.

The objective of this study was to determine which of the two forms of fertilization is the best available for the three major elements (NPK) to maize for optimal growth, but also to determine or specify for each form of fertilization; the optimal NPK dose (s) allowing the farmer to obtain the best yield and increase the maize productivity in the province of South Kivu.

MATERIELS AND METHODS

Materiels

The vegetative material used was essentially a maize variety (*Zea mays*) named ECAVEL1 and PNK fertilizer the solid and liquid form as non-plant material.

Experimental environment

The experiment was conducted at INERA-Mulungu, located 30km north of Bukavu City on Bukavu Goma Road. This study was conducted from February to June 2013, at the Cirhumbi. Experimental Site located at 1700 meters elevation, 020 18 'south latitude and 280 47' east longitude, according to GPS coordinates.

Climatic conditions

The total annual precipitation in the research station is 1572, 4 mm on average with nine months of rain and three months of dry season. The maximum daily temperature is 24.2 ° C and the minimum temperature is 13.9 ° C; with an average of 19.1^{0}c. The climate is thus of the type AW3 according to the classification of Koppen (Anonymous, 2010).

Table 1. Rainfall data during the study period.

Month	Rainfull (mm)	Number of rainy days
February	173,1	9
March	362,6	20
April	227,4	15
May	63,5	8
June	0,9	1
Total	827,5	53

Inera Mulungu Climatic Station, 2013

It is found that the amounts of rainfall collected during the cropping season meet the requirements of corn. The cumulative rainfall during the test (827.5 mm) far exceeds the minimum of 250 mm rain required for good maize production (Nyabyenda, 2005). It was found that the precipitation during the study was not well distributed. The months of March and April were the most rainy. Rouanet (1984) and Ristanovic (2001) point out that a poor distribution of rainfall during the growing season can be a production constraint for maize.

Methods

Experimental apparatus

The experimental device adopted was a plit- plot with three replications, each replications consisted of 8 plots. The experimental unit was 16 m^2, the plots were 1 m apart; the blocks were separated by 1.5m, in total the test consisted of 24 parcels. The two forms of fertilization: solid fertilization (FS) and liquid fertilization (FL) and the four increasing doses (D1, D2, D3, D4) were the study factors for this work. Of two factors studied, the fertilization forms consisted of 2 variables including FS and FL. While the doses had 4 levels of which: D1 = 40 kg of NPK ha^{-1}, D2 = 70 kg NPK ha^{-1}, D3 = 100 kg NPK ha^{-1}, D4 = 130 kg NPK ha^{-1}.

Field preparation and sowing

Two plowings was done. The delimitation of the blocks and parcels was done by picketing. Online seeding was conducted in February 2013 at a rate of three grains seedling^{-1} approximately 5 cm deep, following spacings of 80 cm × 50 cm; which gives 5 lines of sowing with 8 plants; in total 40 plants on a plot of 16 m^2.

Contribution of NPK

Fertilization consisted of two forms of solid and liquid NPK fertilizer made at soil level with the same doses of 40, 70,100 and 130 kg ha^{-1}. The quantities applied at the level of the elementary plots were calculated by extrapolation.

Fertilizer input was split into two applications at 30 days and 45 days after sowing as a cover crop and had proceeded in the following way. Table 2 shows the timing and fractions of fertilizers.

Table 2. Timing and fractions of fertilizers NPK

Solid and liquid NPK	1st month	2nd month	3rd month
Intake NPK	No intake	40%	60%

The application of NPK solid fertilizers was by lateral location by digging a small furrow of 10 to 15 cm around the plants where the fertilizer was applied and covered the furrow with soil. Liquid fertilizers were applied at ground level by watering due to 50 ml of the product in 10L of water by in-line location of seedlings.

Parameters observed / measured

Growth parameters

The vegetative parameters were collected at 5 weeks after emergence until the appearance of the male inflorescence at 21 days intervals on 12 well chosen plants except those of the border or on a useful plot of 4.8 m^2.

Lifting rate: observed at 8 days after sowing this delay is explained by the fact that a small dry time characterized the sowing period and was obtained by counting sprouted plants.

Collar diameter (mm): It was measured with a vernier caliper on 12 well chosen plants.

Height: It was measured by means of a tape measure on 12 plants of the sampling surface.

Performance parameters

Number of ears plant^{-1}: It was obtained by counting on 12 sampling plants.

Length of ear: It was determined by a tape measure.

The weight of fresh ears of corn with husks: It was determined in the field by an ordinary balance.

The weight of dried corn cobs without husks: It was determined by an ordinary balance,

Yield in corn kernels: Calculated by the following formula

$$\text{Rendement} = \frac{\text{Poids de grains par plant x Nombre de plant x 1ha}}{\text{Surface parcellaire}}$$

The weight of 100 grains: was determined by a KERN 440-33N precision scale.

RESULTS AND DISCUSSION

Vegetative parameters.

Neck diameters at 5 weeks (mm)

Figure 1 shows the diameter of the neck of the plants at 5 weeks post-emergence, depending on the form of fertilization and the dose.

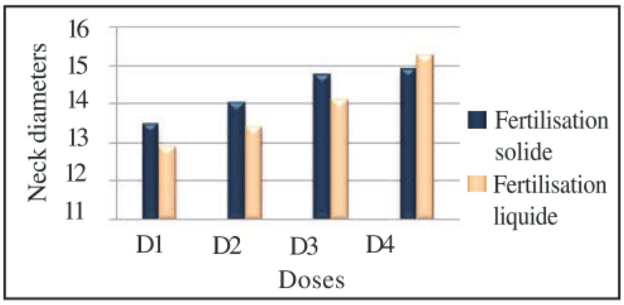

Figure 1. Neck diameter at 5 weeks (mm)

The appearance of this figure 1 shows that the diameter at the neck at 5 weeks after emergence tends to increase with the increase of the dose and that the great value of the diameter was given by the solid fertilization. While the result of the analysis of the variance shows that there was a moderately significant difference between neck diameters at 5 weeks after emergence at the different doses and highly significant at the block level.

As for the comparison of the averages, it appears that the neck diameters at 5 weeks after emergence at the level of the doses form 4 groups: the dose of 130 kg ọf NPK occupies the first position and gave the diameter to the collar the most large, followed by the 100 kg dose of NPK. On the other hand the dose of 40 kg of NPK occupies the last position and gave the diameter to the smallest collar.

Diameters at the collar

Neck diameters at 8 weeks after emergence (mm)

Figure 2 shows the diameter of the neck of the plant at 8 weeks after emergence, depending on the form of fertilization and the dose.

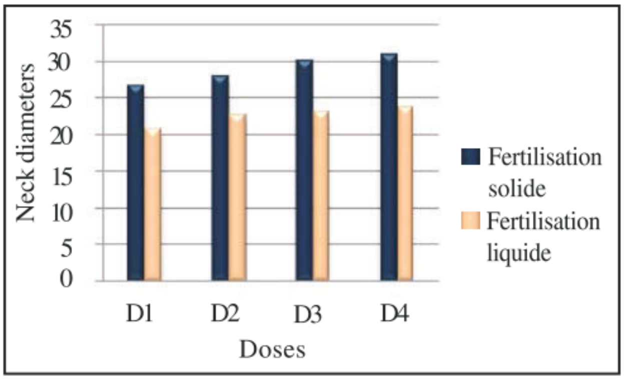

Figure 2. Neck diameter at 8 weeks of emergence (mm)

It is found that at 8 weeks, the neck diameter tends to increase with increasing doses and that the large diameter value was found on the side of solid fertilization.

Analysis of the variance of neck diameters at 8 weeks shows that there is a highly significant difference in neck diameter in terms of fertilization form and moderately significant at the dose level. It emerges from this observation that the neck diameters at 8 weeks after sowing form two groups, as for the comparison of averages, it is observed that the solid fertilization occupies the first position and gave the large diameter to the neck.

Heights of plants at 5 weeks after emergence

Figure 3 shows the evolution of plant height at 5 weeks of emergence as a function of fertilization form and dose.

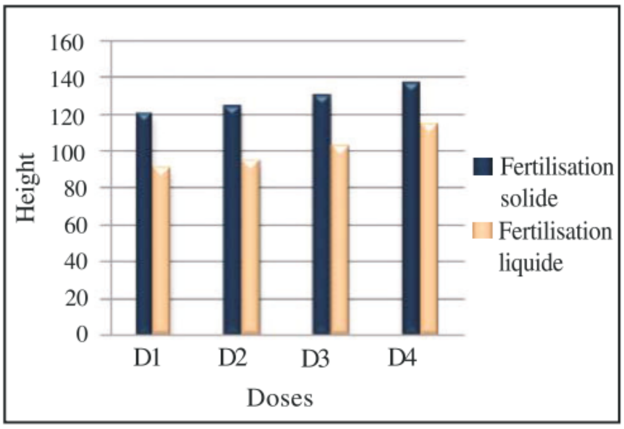

Figure 3 . Plant heights at 5 weeks (cm)

It is observed that plant height tends to increase with increasing doses and that the high value of height is given by solid fertilization.

The summary of the analysis of plant height variance at 5 weeks of emergence as shown by a highly significant difference between height versus fertilization form, dose, and blocks. While comparing the averages of the height of the plants after 5 weeks depending on the form of fertilization. The results showed that solid fertilization occupies the first position and gave the highest height. These results showed that the height of the plants at 5 weeks is divided into 4 groups according to the dose: the dose of 130 kg of NPK occupies the first position and gave the highest height, followed by the dose of 100 kg of NPK which in the second position, however, the doses of 70 and 40 kg of NPK are not significantly different from each other and occupy the last position. Averages with the same letter were not significantly different.

Plant heights at 8 weeks after emergence

Figure 3 shows the evolution of plant height at 8 weeks depending on the form of fertilization and the dose.

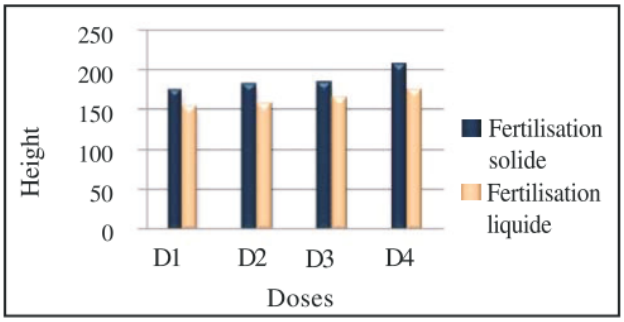

Figure 4 . Plant heights at 8 weeks (cm)

Figure 4 showed by its appearance that the height of the plants tends to increase with the increasing doses and that the highest height was given by solid fertilization.

The analysis of height variance shows that there was highly significant difference between plant height at 8 weeks at the fertilization form and at the 0.05 threshold level. The comparison of plant height averages at 8 weeks after emergence according to the fertilization form is divided into 2 groups according to the form of fertilization: solid fertilization occupies the first position first and gave the highest height. It appears that at the level of the doses it is formed 4 groups: the dose of 130 kg of NPK occupied the first position and gave the highest height, followed by the dose of 100 kg of NPK which occupied the second position. On the other hand the dose of 40 kg of NPK occupied the last position and gave the lowest height.

Number of leaves plant^{-1}.

Number of leaves plant^{-1} at 5 weeks

Figure 5 shows the number of leaves plant^{-1} at 5 weeks after emergence, depending on the form of fertilization and the dose.

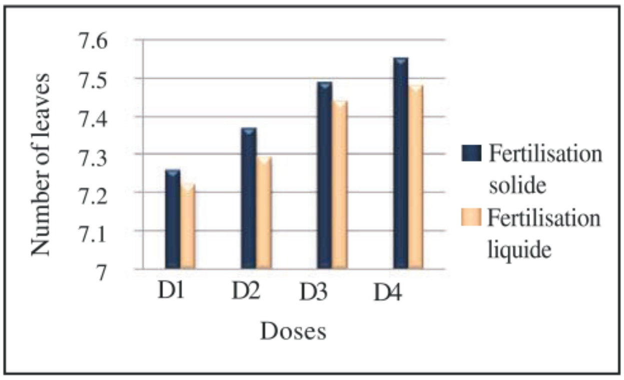

Figure 5. Number of leaves plant $^{-1}$ at 5 weeks

By its appearance figure 5 shows that the number of leaves plant^{-1} increases slightly with the increase of the dose and that the large number of leaves was given by solid fertilization. It follows from the summary of the analysis of variance that the source of variation between the number of leaves at 5 weeks is the dose. The number of leaves plant^{-1} at 5 weeks was divided into 2 groups according to the dose: the doses of 130 and 100 kg of NPK were not significantly different and gave the number of leaves plant the highest occupying the first position.

Number of leaves plant^{-1} 8 weeks of emergence

Figure 6 shows the number of leaves plant^{-1} at 8 weeks post-emergence, depending on the form of fertilization and the dose.

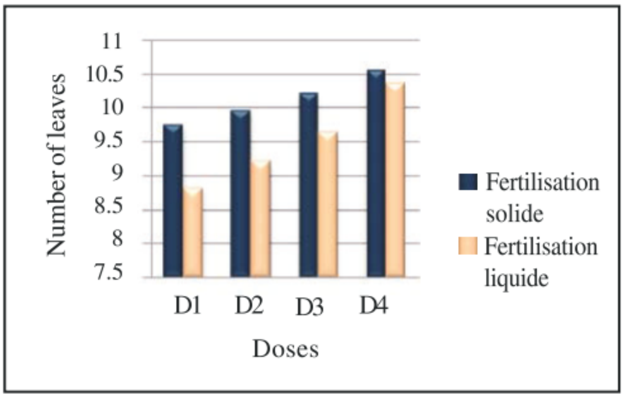

Figure 6. Number of leaves plant^{-1} at 8 weeks

By its appearance figure 6 shows the number of leaves plant^{-1} increased slightly with the increase of the dose and that the high number of leaves is on the side of the solid fertilization.

Analysis of the variance shows that there was a moderately significant difference in the number of leaves plant^{-1} and a low level of blockiness in the form of fertilization and the dose. It appears that the number of leaves plant^{-1} at 8 weeks was divided into 2 groups according to the form of fertilization: solid fertilization occupies the first position and gave the highest number of leaves compared to liquid fertilization. The comparison of means shows that the number of leaves plant^{-1} at 8 weeks after emergence at the level of the doses form 4 classes: the dose of 130 kg of NPK occupied the first position and gave the highest number of leaves, followed by the dose of 100 kg of NPK which occupied the second position. On the other hand the 40 kg dose of NPK occupied the last position and gave the lowest number of leaves.

Performance parameters

Number of ears plant^{-1}

Figure 7 shows the number of ears plant^{-1} depending on the form of fertilization and the dose

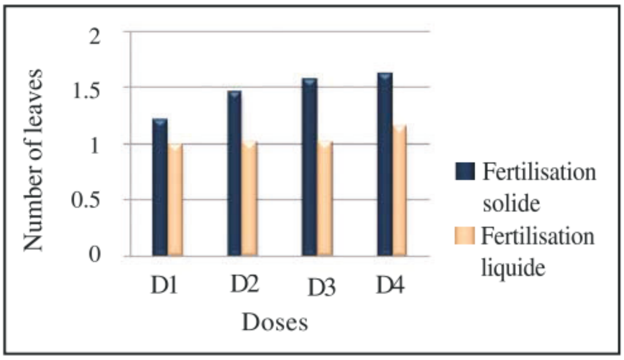

Figure 7. Number of ears plant^{-1}

This figure 7 shows by its tendency that the number of ears was high at the level of the fertilization and at the level of the high doses.

The analysis of the variance in number of ears plant^{-1} shows that there was a very significant difference in the number of ears plant^{-1} depending on the form of fertilization and moderately significant in the dose and at the block level. The number of ears plant^{-1} is divided into 2 groups according to the form of fertilization: solid fertilization occupies the first position and gave the highest number of ears plant^{-1}, i.e. on average 1.47 compared to liquid fertilization. which gave an average of 1.05. Comparison of the average number of ears plant^{-1} according to the dose. The number of ears plant^{-1} is divided into 4 groups according to the dose: the dose of 130 kg of NPK occupied the first position and gave on average the number of ears plant^{-1} the highest compared to the lower doses.

The weight of fresh ears of corn.

Figure 8 shows the weight of fresh corn cobs by fertilization form and dose.

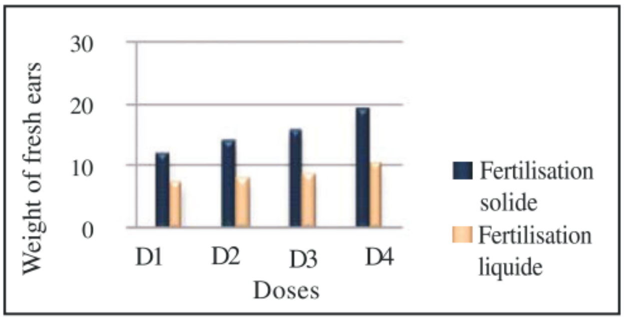

Figure 8. Fresh corn cob weight (T ha^{-1})

The appearance of this figure 8 shows that the fresh weight of corn increased with the increased dose of fertilzer and the highest weight of fresh corn was given by solid fertilization. Variance analysis shows that there was a highly significant difference between fresh corn weight and moderately significant block level at the fertilization form and dose level.

The weight of fresh ears of corn is divided into 2 groups according to the form of fertilization: solid fertilization is in the first position and gave the highest weight of fresh corn cobs averaging 15.42 T ha^{-1}compared to the liquid fertilization that gave on average 8.68T ha^{-1}. It has been shown that there are 4 significantly different groups of fresh corn cob weights: the 130 kg dose of NPK occupied the first position and has the highest weight of fresh ears compared to the lower ones.

Weight of dry ears of corn without spars

Figure 9 shows the weight of dry ears of corn without spars

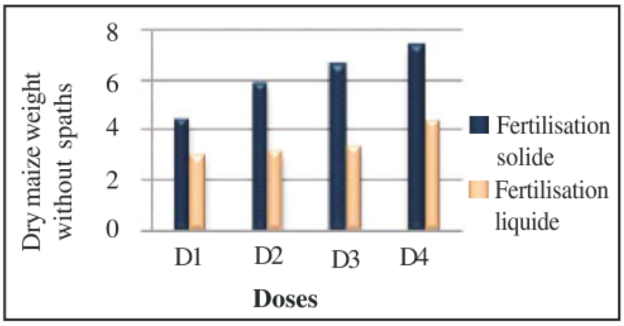

Figure 9. Weights of dry ears of corn without spars

The appearance of this figure 9 shows that the dry weight of corn without spars increased with the increase of NPK doses. Analysis of the variance indicates that there was a highly significant difference between the weight of dry ears of corn without spars, depending on the form of fertilization, the dose and at the block level. The comparison of the weight averages of dry ears of corn without spars according to the form of fertilization shows that the weight of dry ears without spars of corn is divided into 2 groups according to the form of fertilization: the solid fertilization occupies the first position and gave the weight of dry ears of corn without spars the highest average of 6.08T ha^{-1} compared to the liquid fertilization which gave an average of 3.46 T ha^{-1}. For example, a comparison of dry spike weight averages of 130 kg of NPK gave the dry weight of dry ears higher than the lower doses.

Weight of 100 grains of corn

Figure 10 shows the weight of 100 corn kernels depending on the form of fertilization and the doses.

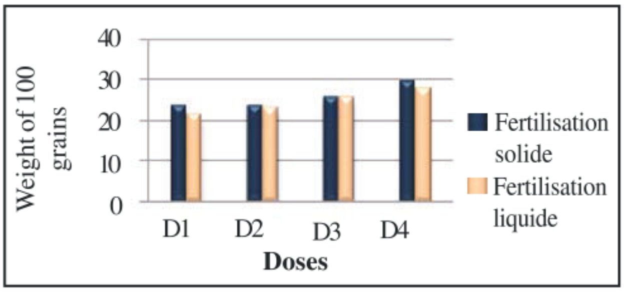

Figure 10. Weight of 100 corn kernels (g)

Figure 10 shows the weight of 100 grains increases slightly with the increasing doses.

There was therefore a highly significant difference in the weight of 100 corn kernels depending on the form of fertilization, dose and block level. It is found that the weight of 100 maize grains is divided into 2 groups according to the form of fertilization: solid fertilization occupied the first position and gave the weight of 100 maize grains the highest, on average 26.57 g compared to the liquid fertilization which gave on average 24.57 g. Thus, the dose of 130 kg of NPK occupied the first position and gave the weight of 100 grains the highest, followed by the dose of 100 kg of NPK occupied the second position against the 40 kg dose of NPK a gave the weight of 100 grains the lowest.

Yield in corn kernels

Figure 11 shows maize grain yield as a function of fertilization form and doses

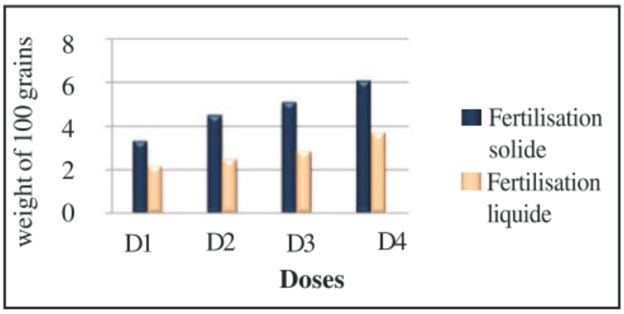

Figure 11. Maize grain yield (T ha^{-1})

Figure 11 shows that grain yield increased with the increasing doses and high yield tends to be obtained with solid fertilization. Thus, variance analysis shows that there was a highly significant difference in maize grain yield by fertilizer form, dose and block level. This study showed that maize yield is divided into 2 groups according to the form of fertilization: solid fertilization was in first position and yields the highest maize yield, ie an average of 4.72 T ha^{-1}. compared to liquid fertilization which yielded on average 2.77 T ha^{-1}. It emerged from this study that the dose of 130 kg is in the first position and gave the highest grain yield is an average of 4.84 T ha^{-1} against the grain yield remains lower with the dose of 40 kg of NPK with an average yield of 2.71 T ha^{-1}.

Soil fertility is one of the key factors in agricultural production. This study focused on the two forms of fertilization (liquid and solid) of NPK in order to determine the one that makes more available nutrients at different vegetative stages of the plant for the increasing dose of 40 kg, 70 kg, 100 kg and 130 kg of liquid NPK and solid. Plants fertilized with the 130 kg dose of NPK were found to have a large neck diameter. This would be due to the fact that the nitrogen dose has been available to the plants in sufficient quantity relative to the other doses. Since nitrogen is the most important element for plant life, its extract from the air by some plants or soil, nitrogen is the engine and is used to build all the green parts that ensure growth. and plant life (Anonymous, 2005).

Thus, nitrogen being the driving force for the growth of the plant (Ali, 2007), it is very soluble, poorly retained on the adsorbent complex and therefore particularly sensitive to leaching. Plants fertilized with liquid fertilizers gave a small diameter to the collar because these fertilizers are already in the soluble state; a part of the elements brought mainly nitrogen would be lost by leaching. This phenomenon would be justified during the test, in that the moment of application of liquid fertilizers coincided with a period of many rains. Rainfall data provided by table 1, shows it very visibly.

Regarding the growth in height for our experiment, the contribution of the 130 kg dose of NPK on maize gave high plants because nitrogen and phosphorus are the most important elements for growth in height of maize plants essential for the construction of the stem. The growth rate in height is in first approximation directly proportional to the quantities of P_2O_5 introduced (Mazard and Arraghi, 1980).

When to the numbers of leaves, especially the number of leaves plant^{-1} is a more varietal character. However, its variation would be due to the height increase which favors the formation of additional leaves along the stem. But also the role of nitrogen in cell divisions would play an effect.

For corncobs, the number of ears plant^{-1} being a trait related to the variety, it was found that the variation in the number of ears plant^{-1} at the level of the doses would be influenced by the amount of P_2O_5 contributed by the different species / doses. In fact, phosphorus plays a determining role in floral induction and the number of flowers plant^{-1}. Therefore, a phosphorus deficiency causes a decrease in the number of flowers but also the number of ears (Anonymous, 2013). The dose of 130 kg of NPK occupied the first position and gave the highest weight of fresh ears as compared to lower doses. This parameter is on the one hand directly related to the number of ears plant^{-1} and on the other hand to the quantity of N and K added since these two elements intervene respectively in the synthesis and in the formation of the proteins as well as their migration to reserve organs (Unifa, 2005).

Plots fertilized with the NPK liquid form gave a low grain yield because these fertilizers were already in the soluble state, a quantity of nitrogen brought would be leached since the spreading period was characterized by many of them. e.g. rainfall. In fact, nitrogen is the mainstay of crop fertilization, which is a limiting factor in maize yield, and the contribution of P is equivalent to the suppression of a limiting factor, with the consequent increase in yield (Bourbie, 2012).

Mineral nutrition being properly ensured then the necessary mineral elements are present in the soil in a satisfactory quantity and proportion. The inadequacy of one element limits the effectiveness of others (Naughty, 1997). In fact, the significantly high yield on the plots fertilized with the dose of 130 kg of NPK could be due to release of the important elements N, P and K in large quantity necessary for the growth and the optimum development of the maize.

The highest average yield obtained was 4.8 t ha^{-1} which is consistent with the results of Nyembo (2010) and Anonymous (2008), locating the average maize yield in the order of 4 to 8 T ha^{-1} in farms with the use of improved varieties and the use of mineral fertilization.

A study was conducted at the research station in order to determine on both forms of fertilization (solid and liquid) with four increasing doses: 40, 70, 100 and 130 kg ha^{-1} of NPK for each of the forms of fertilization has a better yield of corn.

The results of this work show that: The recovery rate for the variety used was satisfactory with an average of 98%, the results of the analysis of the variance and the comparison of the averages of the vegetative parameters showed that the latter were influenced by the fertilization form and the dose with large NPK solid fertilization values, the yield parameters also varied according to the form of fertilization and at the dose level: the number of ears plant^{-1} The weight of fresh ears of wheat with spaths, the weight of dry ears without spaths and the grain yield increased with increasing NPK doses. The 130 kg dose of NPK significantly increased yield compared to plots fertilized with lower doses or that yielded 4.8 tons ha^{-1} on average.

Given these results, the solid form of NPK remains the best form of intake of these three major elements to the corn crop, given the edapho-climatic conditions of the study environment in particular and the province as a whole. But also, we recommend to farmers farms with conditions similar to those of Mulungu, to use the dose of 130 kg of NPK to increase their production, which hardly reaches a ton ha^{-1} at the farm level.

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