ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 11, pp.22424-22428, November, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

PHOSPHORUS APPLICATION BASED ON TIME AND DIFFERENT FERTILIZER'S SOURCES EFFECT ON MAIZE (*Zea mayze* L.) PRODUCTIVITY IN KIRINGYE SITE OF RUZIZI PLAIN IN SOUTH KIVU OF DEMOCRATIC REPUBLIC OF CONGO

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ARTICLE INFO

Article History:
Received 08th August, 2015
Received in revised form
15th September, 2015
Accepted 15th October, 2015
Published online 30th November, 2015

Key words:
Degradation,
Yield,
Soil,
Inorganic fertilizers,
Phosphorus

ABSTRACT

Land degradation is a crucial constraint of crop production across the world, especially for the developing countries with low income to invest in good and profitable cropping technologies. Different engagements have been taken by the head of different African states to improve the use of inorganic fertilizers, as a key factor of crop production improvement, but with few successes. The Abuja commitment has been adopted but now it is expiring with few results. In South Kivu from the East of DR Congo, different organizations have tried to disseminate the use of these inputs but the end users are still unpowered. In Ruzizi plain, Phosphorus limits highly crop production. This study was focused on different Phosphorus fertilizers with specific moments of application to improve maize production. The trials have been installed in a split plot design, with the rate of 60 $Kgha^{-1}$of $P_2 0_5$ from three P-fertilizers sources: DAP, TSP, NPK. All the fertilizers were applied two and one week before the planting date and at the planting date. Results revealed that application before planting date gave good yield and plant growth compared to the application at the planting day, as it is done commonly by the few farmers using these inorganic fertilizers. The NPK and the DAP gave good yield (3, 9 tha^{-1} and 3, 8 tha^{-1} respectively) compared to the TSP (2, 8 t ha^{-1}). Therefore, it is very important to reduce loses of the nutrients by applying phosphorus some days before plating.

Citation: Bashagaluke Bigabwa Janvier *et al.* 2015. "Phosphorus application based on time and different fertilizer's sources effect on maize (*Zea mayze* L) productivity in Kiringye site of Ruzizi plain in south Kivu of democratic republic of Congo" *International Journal of Current Research*, 7, (11), 22424-22428.

INTRODUCTION

Soil fertility depletion in sub-Sahara Africa is a big constraint for increasing food to feed the ever-growing human population (Mugwe *et al.*, 2007). There is limited availability of additional land for crop production, along with declining yield growth for major food crops. Decreasing soil fertility has also raised concerns about the sustainability of agricultural production at current levels (Bationo *et al.*, 2004, Pypers *et al.*, 2011). Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively, and sustainably than in the past. Integrated management of the nutrients needed for proper plant growth, together with effective crop, water, soil, and land management, will be critical for sustaining agriculture over the long term. These calls for integrated soil fertility management (ISFM) techniques that will help improve the agricultural systems (Vanlauwe *et al*., 2010).

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In general, crop use of any nutrient depends on a two-step process: soil supply of that nutrient in an available form, and uptake of that available nutrient by the crop (Sanchez *et al.*, 1997). The two approaches are also affected by many other factors such as the solubility, stage of the plant for the need, ecological factors. Nitrogen, Phosphorus and Potassium are the most important soil nutrients for the crop nutrition and their forms in the soil affect strongly their absorption by the plants. Most of the fertilizers available actually in the markets in South Kivu have two or all of them (three). Phosphorus (P) is one of the essential elements for plant development and the amount of available P and its form in the soil are often inadequate to meet plant requirements. Phosphorus is a macronutrient that plays a number of important roles in plant. Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity (Reddy *et al.*, 2005). Most of the tropical soils are deficient in Phosphorus, due to the high rate of P sorption and leaching of exchangeable cations by ending with aluminum and ion oxides. According to Bationo (2004), around 80% of SSA soils are deficient in Phosphorus. To correct it, the organic matter are not enough , because not only of the availability

(IFDC Catalist, 2010) but also with the weather condition of the continent affecting strongly the quality of it during the mineralization processes, the parental materials are originally poor in Phosphorus in SSA. Recently, farmers, especially in the developed countries, make use of organic manure which has been found to be effective like inorganic fertilizers for the release of some nutrients especially phosphorus but the resultant yield has been found not to be as high as when inorganic fertilizer is combined with the organic manure (Vanlauwe *et al.,* 2010; Mugwe *et al.*, 2007 Mugendi *et al.*, 2010; Muheru-Muna, *et al.*, 2010; Pypers *et al.*, 2011. In the DR Congo, soil nutrient deficiency is acute although different studies (DSRP, 2005) characterize the region with a high potential of soil fertility. This can be understood for forest areas where there is low population density due to other constraints of life, but the rest of the country is highly degraded with the continuous cropping with poor nutrient's management. In Ruzizi Plain, with sandy soils in general, Phosphorus is the most constraint of plant nutrition within that region. The low P assimilation doesn't facilitate soil particles and structure improvement. In order to meet the need of phosphorus in these soils for the development of crops, farmers have to use inorganic fertilizers for their crops. However, P fertilizer is not readily available to these farmers because of scarcity in some cases and also due to the high cost of these fertilizers (Ayub *et al.,* 2002). But in some areas of the countries, especially the sites where there are some project's activities, farmers have started to use these inorganic inputs. Because of the number of products on the market, the selection of a phosphate fertilizer can be confusing, it is therefore very crucial to have some rational criteria to select efficiently the correct inputs as source of Phosphorus.

In Ruzizi plain, phosphorus is more deficient than the two other elements. However, during the harvesting of the trials with phosphorus based fertilizers and the inputs were applied the planting day, some components of them could be observed on the ground. This means that, new activities are to be, therefore, focused on a specific fertilizer to use by adjusting the time of their application to maximize the use by the plants. From the market, the different fertilizers have different P concentrations but the prices for all of them are closely the same. The current study focused in general to sustain and increase maize production in South Kivu by managing and sustaining the nutrient's supply for better maize production. It is, especially, selecting the good time of application of phosphorus fertilizers to improve the growth and the yield of maize. Avoiding loses of nutrients and the economic efficiency should guide any farmer committed to invest into the new cropping technologies based on fertilizer's use.

MATERIALS AND METHODS

This study was carried out in Ruzizi plain located in Uvira territory of South Kivu province. It is dominated by lowland has borders with Rwanda and Burundi. The annual precipitation average of the study area is 1300 mm with a maximum of 1600 mm and minimum of 800 mm. The average for temperature is annually 22,5-25 °C with a maximum of 30,5° à 32,5°C in September and a minimum of 14,5 - 17°C in july. The soil is dominated by two types: sandy clay and clay sandy. To assess the objectives of this study, an experimental trial was installed in a split plot design with three replications. The Land preparation was done manually as a common farming system in the area two times and the last was done one week before the first application of the fertilizers. The fertilizer's type was considered as a secondary factor with 3 levels: DAP (Diammonium phosphate with 46% of P_2O_5), TSP(Trisuperphpshate with 46% of P_2O_5) and NPK 17-17-17 with 17 of P_2O_5 and the time of application as the major factor with three levels: two, one week before the planting and the planting day for each fertilizer respectively names 2WBP: two weeks before planting, 1WBP: one week before planting and control2(PD: planting day). With the rate of 60 Kgha^{-1} of P_2O_5 used, each fertilizer was applied with the following quantities: DAP: 130, 43 Kgha^{-1}, TSP: 130,43 Kgha^{-1} and NPK 17-17-17 : 352,94 Kg ha^{-1} . The following quantities per plot of 12 m^2 were used: 0,15 Kg 0,15 Kg 0,42 Kg for DAP, TSP and NPK17-17-17 respectively. Each single plot has the size of 12 m^2 (3m x4m). ~~The~~ Blocks were separated each other with 1m from all directions. The density of planting was 1500 hills ha^{-1} with the spacing of 75 cm x 50 cm with two grains per hill. For the application time, there was another treatment: control 1: without any fertilizer. This option of different times of application was to give the answer of the objective based on maximizing phosphorus absorption. After the application, before the planting, the fertilizers were covered by the organic matter (mulch) to maximizing soil moisture and avoiding any loss. Before the plantation, the seed did not have any specific treatment to stimulate the germination.

According to Bibey (2014) ECAVEL, the variety used had the following characteristics: Origin: ISABU/ Burundi,
Date of introduction: 2010,
Maturity duration: 90-100 days,
High rain resistance: good,
Drought resistance : good,
Potential yield: 6 to 8 t ha^{-1}).

The trial was installed during the main cropping season A 2015 (October 2014) and the harvesting occurred in January 2015. The observations were carried out on growth and yield parameters to test the effect of the different factors used. The statistics were based on the analysis of variance using the Duncan test for the means separation.

RESULTS AND DISCUSSION

Growth parameters

Among the essential nutrients, phosphorus is one of the most important nutrients for higher growth in larger quantity (Hussain *et al.* 2006) and controls mainly the reproductive growth of plant (Wojnowska *et al.,* 1995). Generally, P is the second most crop-limiting nutrient in most soils. It is second only to nitrogen in fertilizer use. Plant growth behavior is influenced by the application of phosphorus (Jan and Khan, 2000; Khan *et al.* 1999). Tables 1 and 2 present the results based on the parameters growth (leave's number and plant height, plant diameter) affected by the different factors: the different fertilizers and their time of application.

a) Leave's number per plant and plant height

The early application of the fertilizers has significantly affected the number of leaves. With the difference of 1, 3 per plant, one hectare should produce 39000 more leaves (with an average of 30000 plants ha^{-1}) than the treatment with the

fertilizer application at the planting day. This amount of leaves will affect positively soil properties through the organic matter. Early application of the fertilizers will increase the crop biomass that will be an add value for the soil proprieties improvement. This is a very good option, especially within the areas with few amount of organic matter available. The early application makes the fertilizer more soluble to be sued by the plant.

Table 1. The effect of application time and the different fertilizers types of plant leave's number and plant height (cm).

	Leave's number	Height
Time of application		
2WBP	15,33a	208,33a
1WBP	15,34a	205,44b
Control1(PD)	15,1b	200,83 c
Control 2 (0F)	14c	166,85d
Lsd	0,019	1,255
	15,68 a	206,16 a
Fertilizer's type		
DAP		
NPK	15,67 b	208,78 b
TSP	13,76c	171, 15 c
Lsd	0,02	0,019

The control 1 (without any fertilizer) gave the lowest number of leaves (14). This confirm the need to supply the soil with some external inputs to improve the plant growth and reduce the accurate degradation of the soil related to the poor nutrient's management due to different interacting factors. And according to Vanlauwe *et al*. (2010), Bationo *et al*. (2007), Sanginga and Woomer (2009), soil nutrient's management requires the involvement of different functioning approaches through the integrated soil fertility management. For the input's type effect on the leave's number, in general, plots with phosphorus mixed with Nitrogen gave good values of leave's number($P<0.001$). This will be profitable to the soil organic matter accumulation in the soil. The important number of the leave's number, although this is genetic factor, is related to the Nitrogen supply from the fertilizers. This is good option to sustain soil organic carbon by increasing crop biomass with good cropping systems. With the difference of two leaves per crop, and with the density of 15000 hills and with two plants per hill, one hectare with P-N fertilizers should have 60000 leaves more compared to the TSP. This amount of leaves is extremely high to improve soil organic matter, which, however, should also good management to be more benefic to soil. It should be, therefore, better to be more focused on the two fertilizers (DAP and NPK); but after comparing the other parameters, in order to select one which could be more efficient for farmers in term of biomass production , yields increasing and income increasing.

For the application time of the phosphorus input effect on plant's height, in general controls (1 and 2), are different from the other treatment statistically. This confirms the need for a good time of application and also the importance of external inputs to improve plant growth (control 1, without any input is statistically different from the other treatments). Between the two early applications, fertilizers, applied two weeks before planting, gave high values (208, 33 cm per plant) than fertilizers applied one week before planting (205, 44 cm per plant). However, maize with high value of height should be more sensitive to wind. But the important growth of the diameter is a good option to reduce the effect of the wind. The effect of the different fertilizers on the plant height has shown that the combination of the three elements (NPK) gave the highest values of the plant's height (208, 78 cm per plant). Similarly to our results, nitrogen in combination with P and K greatly influenced the vegetative growth and plant height of maize (Asghar *et al.,* 2010). The treatment with N and P combined (DAP), produced the second highest plants (206, 16 cm per plant). The earlier application of the fertilizers gave crops with high values of height that could make them sensible to wind but the increase of the diameter should give more resistance to the plants.

b) Plant Diameter

Statistical analysis of the data indicated that nutrients combination with application time and interaction had significant effects on plant diameter (cm) (Table 2).

Table 2. The interaction effect of the different phosphorus fertilizers with the time of their application on the plant height (cm)

Sources of P x times of application	Means
NPK x 2WBP	29,69a
DAP x 2WBP	28,96a
NPK x 1WBP	27,69a
DAP x1WBP	25,53bc
TSP x 2WBP	24,65bc
NPK x control2	23,43 cd
DAP x control2	23,37cd
TSP x 2WBP	22,29de
TSP x control 2	21,27 ef
Control 1	19,82f
Lsd	2,141

Results from Table 2 show interaction between the time of application and the fertilizer's type. NPK and DAP fertilizers applied before planting gave good values for the diameter. All the groups of late application associated to all fertilizers and the groups with TSP for all periods gave the lowest values. Phosphorus from TSP and all applications at the planting day did not improve well the plant diameter growth. For a good plant diameter increasing, fertilizers with P associated to N are more recommendable. Among the two products, NPK and DAP, both with the two elements of interest , the concentration of them will guide the choice, but also combining with other factors such as the effect on other growth an yield parameters, the effect on soil properties and the price. However, locally, most of the fertilizers don't differ with the price, but the other factors should remain observed for any recommendation among the two.

Yield parameters

Yields parameters as affecting the two factors: time of application and the fertilizer types, are given in table 3.The treatment of the two factors, under study, are statistically different for the studied yield parameters (number of grains per ear and yield (tha^{-1})) are statistically different. For the input's effect on number of grains per ear, fertilizers applied two and one week before the planting day presented a high values of grains number compared to the two controls: plot without fertilizer and the plot where the inputs were applied the planting day. This means that Phosphorus applied before

planting through the different types has a positive impact on the crop yield due to the low solubility of P into the soil; therefore it needs more time to be available to the crop (Anonym, 2008). Thus, there is an urgent need to seek strategies by which P fertilizers can be used more effectively in those farming systems where P is currently deficient and where its use is economically feasible (Bibey, 2014).

Table 3. Effect different fertilizers and their application time to the number of grains par ear and the yield (t ha^{-1})

	Grain number	Yield
Time of application		
2 WBP	492,3a	4,537a
1WBP	513,2a	3,982a
Control2	484,2b	2 ,763b
Control 1	324,9c	2 ,301b
Lsd	19,07	0,398
Fertilizer's types		
DAP	476,3 a	3,89 a
NPK	475 a	3,91 a
TSP	409,4b	2,81b
Lsd	10,71	0,27

In many developed countries, there has been a decline in P fertilizer use, partly for financial reasons, and partly because more P is being recycled through organic manures (e.g. animal manure, green manure and compost). Where plant-available P levels are well above the appropriate critical value for the soil and farming system under consideration, there is also a need to use fertilizer P more efficiently (Dodd and Mallarino, 2005).When P is required, both the amount applied and the timing of the application is important for improving the efficiency with which the P is used. Phosphorus absorption is more progressive than the two other macronutrients: N and K (Gigou and Traoré, 1987). Grain formation is strongly affected the mineral nutrition, especially with the presence of Nitrogen. DAP and NPK both have nitrogen and they have shown high number of grains. Both elements are involved in amino acids formation and should strongly affect the number of grains. The presence of Potassium in NPK fertilizer did not influence the number of the grains compared to DAP with only P and N**.** According to Gervy (1970), nitrogen and phosphorus are the important elements of grains formation. Nitrogen will not only improve the plant growth but the concentration of proteins.

Results for the timing effect on the yield have shown that, for the two early applications, the yield is better compared of the application during the plating day (contro1: PD). For both early applications, the increase is of 64, 2% (1, 8 tons ha^{-1}) and 44, 1% (1, 2 t ha^{-1}) from 2 and one week respectively compared to the control 2 (application the planting day). This explains how the crop used efficiency the fertilizer applied early than the ones of the planting day. As it is visible, the two control are statistically the same (both in b group at 5 %). For the application of the fertilizers, the yield increased, due to the inorganic fertilizers used , up to 97 % (2,4 t ha^{-1}), 73 (1,7 t ha^{-1}) and 20 % (0,47 t ha^{-1}) respectively for NPK, DAP and TSP compared to the control 1 without any application. The 470 kg of difference from TSP with the control, confirm that, although there is application of fertilizer, this source don't meet the requirement of the maize as a good source of P compared to the others (DAP and NPK) due the presence of Nitrogen in both fertilizers. Phosphorus is a macronutrient that plays a number of important roles in plant. Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity. Hussain *et al*. (2006) and Nawaz *et al* (2004) stated that phosphorus deficiency is one of the largest constraints to food production in tropical African soils due to low native P and high fixation by iron and aluminum oxides. But it is therefore better to use adequate sources to increase the plant use efficiency. There is a need to increase the use of P fertilizers in most developing countries in order to ensure food security for their growing populations. Soils containing insufficient amounts of plant-available P not only produce economically unacceptable yields, but other inputs, particularly N, are also used less effectively.

For the fertilizer's type effect on the yield, The NPK and the DAP gave good yield (3,9 tha^{-1} and 3,8 tha^{-1} respectively) compared to the TSP (2,8tha-1). However, the amount of NPK required (352, 94 Kg ha^{-1}) is high compared to the two other (130, 43 Kg ha^{-1}) and the price at the local market is almost the same. The amount of NPK is very important and all the three need the same management, in term of application and any other cropping system. Therefore, any specific reason should push the farmers to use NPK as a source of Phosphorus. For a source of Phosphorus to increase the production, it is crucial to be focused more on DAP. The ratio of the quantities NPK needed per hector with the other fertilizers is higher compared to the ratio theirs productions. This means high amount of NPK compared to the output. Even, NPK, has Potassium, any effect, expressed in high yield and related to the presence of this element, was observed. The NPK input cost should be more than 2,5 times expensive than the two other, when the production ratio don't balance this high cost with a good yield. According to (Asghar *et al.,* 2010), nutrients must be applied at optimal levels to avoid deficiency while maintaining manageable input costs to achieve high yield. Amanullah *et al* (2010), Amanullah (2010.) suggested that application of essential plant nutrients in optimum quantity and proper time of application is the key to increased and sustained crop productivity and profitability.

Conclusion

There is a need to increase the use of P fertilizers in most developing countries in order to ensure food security for their growing populations. Soils containing insufficient amounts of plant-available P not only produce economically unacceptable yields, but other inputs, particularly N, are also used less effectively. This study aimed to evaluate the effect of early application of different phosphorus fertilizers, came up with different findings profitable to increase the fertilizer's efficiency.

For the application time, it has been found that early application of phosphorus fertilizer has good impact both on growth and yield parameters. This time before planting allows the fertilizer to be more soluble by realizing the nutrient progressively the nutrients for the coming plants.

For the different fertilizers of phosphorus, both the phosphorus fertilizes with nitrogen (NPK and DAP) gave higher values compared to the TSP for growth and yield parameters. The most important and more valuable among the two best should be DAP due to the low concentration of NKP for the nutrients

(N and P) and that could make the price higher for the same amount of nitrogen and phosphorus required.

For the coming studies, is better to focused on more days before planting and getting information on the behavior of nitrogen when is combined with phosphorus within a same fertilizer and applied some days before planting.

Acknowledgment

The authors thanks VLIR-UIC for funding the research through the project: Gestion des ressources au Kivu dans le cadre de la reconstruction post-conflits, volet agronomique based of natural resources management in post conflict region of led by Prof Roel Merckx from KULEUVEN of Belgium . Also, the project administration "cellule de gestion" for the facilities during the field trip; all technicians and students who were involved in the trial's installation and data collection, the owners of the farms for availing the land, are also to thanks for this end.

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