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Evaluation of the productivity of seven varieties of wheat (*Triticum aestivum*) through integrated soil fertility management in Kaziba, South Kivu, DR Congo

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Introduction

1 Every year, more than 600 million tons of wheat are harvested around the world, making wheat the second most widely cultivated cereal in the world after maize [1; 2; 3]. Wheat is the foremost cereal in terms of international trade, with 127 million tons of wheat being bought and sold in 2010 [4; 6; 7]. Wheat is a temperate climate crop, sensitive to high temperatures: for every 2°C rise in the daily temperature above 18°C, the potential yield of wheat diminishes by about 10%.

2 From 1996 to 1998, yields – recorded using varieties imported from France and Italy – oscillated between 200 and 400 kg/ha, depending on the agro-ecological zone (1600 to 2500 m altitude) [12; 13; 8]. In recent years the *Institut National d'Etudes et de Recherches Agronomiques* (INERA) has carried out a series of studies on wheat, conducting adaptation trials on varieties of wheat sown at their facility in order to assess the possibility of introducing varieties well adapted to the medium- and high-altitude conditions of South Kivu. Unfortunately the soils in this area are renowned for their rapid degradation and low fertility: a major constraint on agricultural production in general – and wheat-growing in particular [18; 19; 20; 21; 22].

3 The proposed remedy of mineral fertilization remains, in itself, fragile on soils with a high mobility of Al and Fe, which precipitate with the added nutrient elements. Also, low rural income levels in the region, coupled with the demands of applying mineral fertilizers, often represent a barrier to their acquisition. In this context, combined fertilization should offer an appropriate solution for restoring soil fertility [17; 15; 11]. Combined amendments applied to acidic tropical soils help to increase crop yields by supplying the nutrients necessary for plant growth; the improvement in the physical and biological properties of the soil enables the potential of each variety to be expressed [14; 10; 11; 16].

4 This paper explores the hypothesis that the seven varieties will behave differently in response to NPK, to manure and to NPK + manure. The overall aim is to evaluate the productivity of these seven varieties in response to the various treatments applied.

Environment, materials and method

Environment

Description of the environment

5 The experiment was conducted in a rural location at Kaziba in the territory of Walungu (1835 m, 2°48'31.6'' S, 28°49'13.2" E), 55 km southwest of the city of Bukavu in South Kivu province, Democratic Republic of the Congo.

6 The community of Kaziba is stretched out across the high mountains of the Central African Graben to the east of the Congo River [23], at an altitude of between 1500 and 3200 m; its surface area of 192 km^2 is home to an average of 45,000 dwellings [24].

7 Its humid tropical climate, influenced by the altitude, is characterized by two seasons: the dry season, June to August, and the rainy season, September to May; mean annual temperature is about 19°C in the north and 10°C in the south, and mean annual precipitation is 1200-1700 mm. Above the 2200-m line there are mountain forests and bamboos [25].

Materials and method

Description of the trial

8 The trial was conducted, with three replications, using the split-plot method, the main factors being the variety, with seven modalities (Farari, Kayira, Kima, Lokale, Mbega, Nyumbu and Popo) and the treatment, with four modalities (Control, NPK, Manure, and NPK + Manure).

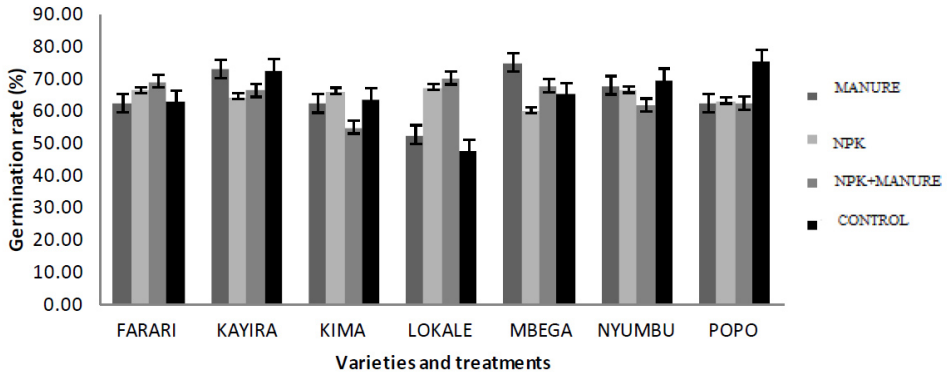
9 The grains of the varieties used (obtained from INERA in Mulungu) were sown in rows 25 cm apart, with 4 grains to each pocket, every 20 cm. They were sown on the same day that the amendments were applied. Well-composted cow manure, with known characteristics, was applied to the plots, buried in the soil just before sowing at the recommended rate of 10 tons per hectare. NPK 17-17-17 was added at 150 kg per hectare. The plots marked for the NPK/manure combination received one half of each type of amendment. Upkeep consisted of regular weeding and ridging. The observations related primarily to the growth and yield parameters, centering mainly on the germination rate,

the days to flowering, days to physiological maturity, number of fertile tillers per plant, number of grains per ear, weight per 1000 grains, and yield. Variance analysis (Anova) was performed to measure differences between varieties and between treatments, as well as their interactions, and Tukey's mean separation test (at 5%) was performed using Statistix 8.0.

Results

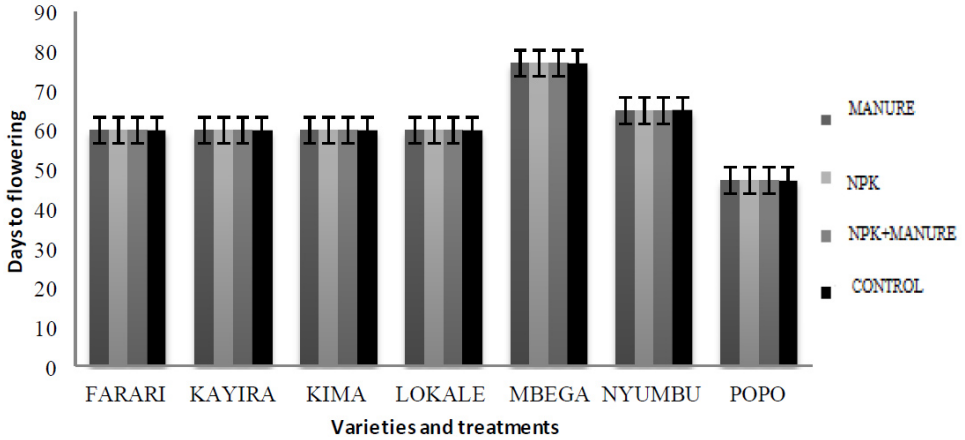
10 The germination rate was not influenced by the varieties (P =0.2531); nor was it affected by applications of fertilizer (P=0.9980) or by the interaction between variety and fertilizer (P=0.3118). The average germination rate was 65.04%.

Fig. 1. Effects of varieties and treatments on germination rate of wheat.



11 The varieties (P = 0.0000) induced highly significant effects on the number of days to flowering. The earliest-flowering variety was Popo, after just 47 days, followed by the Farari, Kayira, Kima and Lokale varieties, which flowered after 60 days; the latest-flowering was Mbega, after Nyumbu, which flowered at 77 days and 65 days respectively.

Fig. 2. Effects of varieties and treatments on days to flowering of wheat.



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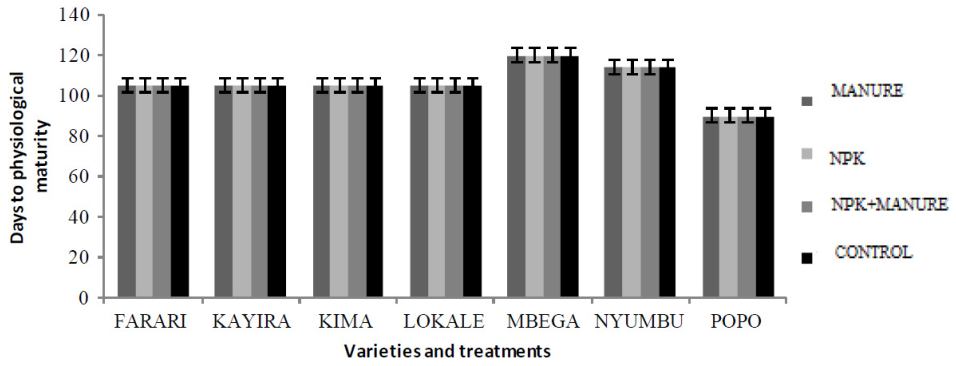
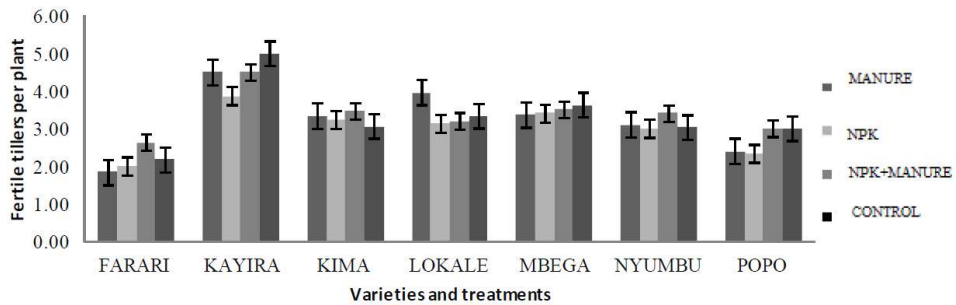
12 The number of days to physiological maturity was correlated only to variety ($P < 0.001$). The overall average for all of the varieties was 106 days; the most precocious variety was Popo (90 days) and the latest to mature was Mbega (120 days).

Fig. 3. Effects of varieties and treatments on days to physiological maturity of wheat.



13 The number of tillers per plant was influenced only by the variety (P=0.0008). Kayira had the largest average number of tillers (4.46), while Farari had relatively fewer tillers (2.15).

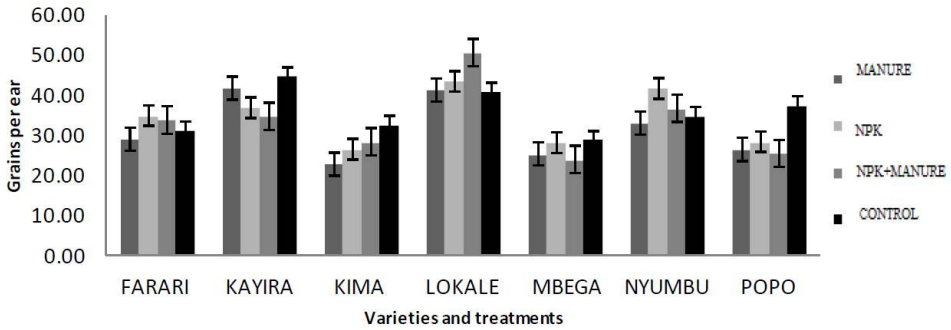
Fig. 4. Effects of varieties and treatments on number of fertile tillers of wheat.



14 Variant analysis reveals that the number of grains per ear was affected both by the variety (P=0.0000) and by the fertilizer applied (P=0.0069), but not by the crossed effects

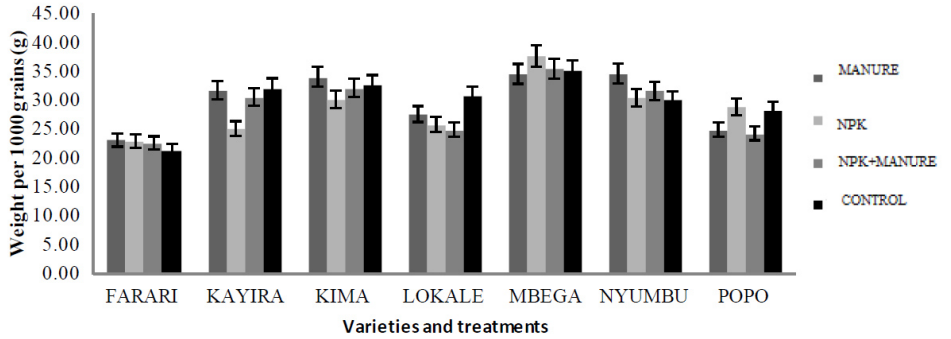
of varietals and treatments (P=0.1247). The variety with the most grains per ear was Lokale (43.817), while Mbega bore the least grains per ear (26.350).

Fig. 5. Effects of varieties and treatments on number of grains per ear of wheat.



15 The weight per 1000 grains was correlated to variety (P=0.0000). The fertilization rate (P=0.3525) and the interactions between these two factors (P =0.5629) did not show an effect on the weight per 1000 grains. The overall average was 29.294 g, with Mbega and Farari at either end of the scale (at 35.56 and 22.39 grams respectively).

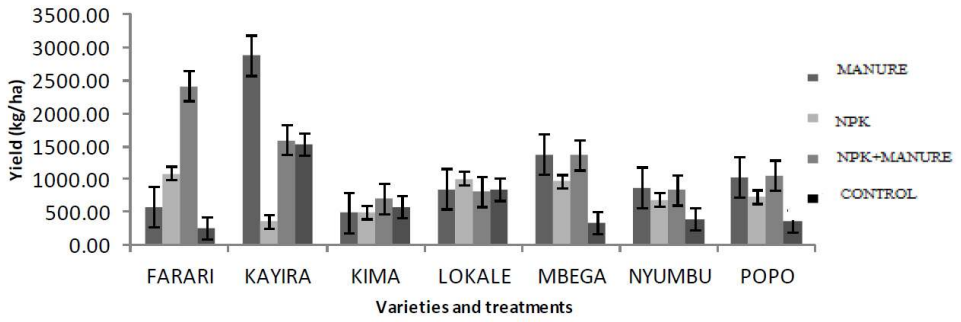
Fig. 6. Effects of varieties and treatments on weight per 1000 grains of wheat.



Yield

16 The fertilizers show significant effects on yield (P=0.0194); the varieties, and the interaction between the two factors, also affect this parameter (P=0.0013 and 0.0022 respectively). The conclusion that emerges is that the plots treated with the NPK + Manure combination (1317.2 kg), produced higher yields than the unfertilized plots (605.1 B) and those treated with NPK (755.4 AB), while those treated only with manure produced values intermediate between the two (1239.6 AB). In terms of varieties, Kayira (1584.2 A) was the most productive and Mbega the least productive. As regards interactions between treatments and varieties, Manure X Kayira (2874.9 kg) and NPK + Manure X Farari (2415.0 kg) produced the best results.

Fig. 7: Effects of varieties and treatments on yield of wheat



Discussion

17 The results of the variant analysis indicate that the factors analyzed, and some of their interactions, affected the parameters studied to different degrees. This demonstrates that the different varieties have different potentials, and that these potentials can be expressed more easily if the soil is amended in the appropriate way. This supports the ideas of several authors who affirm that varieties and cultivars within plant species differ in their growth and development, and that these differences are attributable to the plants' morphological, physiological and biochemical processes and their interaction with the climate, the soil, and any other practice integrated into the crop system [26; 27; 28].

18 According to reference [29] the average yield per hectare is 3.77 tons, too much at variance with our own results, whereas for [30], the yield is 1.92 tons per hectare, partly aligned with some of our results. The plots treated with the NPK + manure combination (1317.2 kg), produced higher yields than the unfertilized plots (605.1B), while those treated only with manure (1239.6 AB) or NPK (755.4 AB) produced yields intermediate between the two. In terms of varieties, Kayira (1584.2A) outperformed Lokale, Popo, Nyumbu and Kima, with the two remaining varieties – Farari and Mbega – ranked in an intermediate position. The crossed effects of fertilizer and variety show that the interaction Manure X Kayira (2874.9 A) produced the best results. This logical sequence in the production capacity of the varieties remains similar to that found at their center of origin [31].

19 These results are confirmed by [32] which states that, in general, the application of organic amendments in combination with chemical fertilizers tends to increase crop yield in comparison to plots where the same fertilizers are used in isolation; [33; 34] show that organic fertilizers have a synergetic effect with chemical fertilizers in tropical soils. The addition of mineral fertilizer – notably nitrogen and phosphorus – could increase the biological activity of the soil and, in so doing, facilitate the effective release of nutrients for the crop.

20 The recorded increase in yield is attributed to the improvement in the soil properties [35] and the release of nutrient elements [36]. Likewise, the increase in yield due to the input of organic amendments is attributable to the favorable change in soil conditions, leading to good root development and good assimilation of the nutrient elements released by the organic matter itself, or through retention of the nutrients released by the fertilizers [37; 38; 39].

21 According to [40], wheat – despite being an under-utilized crop in most tropical ecosystems, unlike other cereals such as maize and sorghum, due to its sensitivity to a range of fungal diseases, its incompatibility with the environmental conditions, and its low yield in these ecosystems compared to the latter crops – could nonetheless have a future thanks to high-performance varieties, appropriate crop systems, and well-managed soil fertility. The results obtained provide sufficient evidence to support that author's position: through use of the right variety, suitable agricultural techniques, and effective management of soil fertility, the yield of wheat was improved to a significant degree.

Conclusion

22 To help promote wheat-growing in rural areas of South Kivu, DR Congo, seven varieties of wheat were evaluated using different fertilizer options: organic, based on cow manure; mineral, with NPK 17-17-17; and organo-mineral, by combining both types. The trials were conducted at Kaziba, a mountainous but densely populated region where the soil is in an advanced state of degradation. The results obtained indicate that wheat-growing is possible in this region, thanks to climate conditions that match the crop's requirements in terms of temperature. Although the soil is severely degraded, this can be remedied using organic amendments (with cow manure) and organo-mineral amendments, making the necessary nutrients available to the plant for its growth and development. Mineral fertilizers alone did not show significant effects on the crop; however, with the use of manure, and its combination with mineral fertilizers, favorable effects were observed. Of the seven varieties proposed by INERA, Kayira and Farari are the preferred options due to their high level of performance. The main recommendation is to use the variety Kayira under cow manure, providing the latter is very well composted and comes from well-fed cattle, and also to facilitate the task of improving soil fertility; combining the manure with NPK offers most additional benefits.

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ABSTRACTS

Due to high demand for food resources as a result of increasing population, the promotion of large-scale crops such as wheat has become essential. Unfortunately, soil infertility and a lack of improved seed are major constraints on the expansion of this crop in Kaziba, a mountainous rural area in South Kivu. The productivity of seven wheat varieties (Farari, Kayira, Kima, Lokale, Mbega, Nyumbu and Popo) was evaluated under organic and mineral fertilizer during the 2013-2014 crop season on poor soil in South Kivu (DR Congo). NPK 17-17-17, farmyard manure and their combination were applied as fertilizers in a split-plot trial design with three replications. The observations focused on the growth and yield parameters, and the results revealed differences between varieties, treatments and interactions. The NPK + farmyard manure treatment gave the highest mean yield (1317.2 kg), Kayira was the most productive variety (1584.2 kg), and the interaction Kayira X farmyard manure was the most effective (2874.9 kg). The variety Kayira would seem to be indicated, with farmyard manure as the recommended fertilizer, being locally accessible and easily usable for promoting wheat in the region.

INDEX

Keywords: wheat, productivity, varieties, poor soil, fertilizers

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