D9593: Results from the Fertilizer demonstration experiment with maize at IOP Farm in Iringa, Tanzania in 2019

Peter Mtakwa, Ndelilio Urio, A. P. Mtakwa, Frank Brentrup, Peter Assey, Marloes van Loon, Renske Hijbeek, Hein ten Berge and Martin van Ittersum

Partner(s): Sokoine Agricultural University, Yara, Wageningen University & Research Centre

Submission date: 20 February 2020

Crop Nutrient Gap Project

The Crop Nutrient Gaps project (full title: Bringing Climate Smart Agriculture practices to scale: assessing their contributions to narrow nutrient and yield gaps) is funded by CGIAR-CCAFS (Climate Change, Agriculture and Food Security), Wageningen University & Research, the International The Crop Nutrient Gaps project (full title: Bringing Climate Smart Agriculture practices to scale: assessing their contributions to narrow nutrient and yield gaps) is funded by CGIAR-CCAFS (Climate Change, Agriculture and Food Security), Wageningen University & Research, the International Fertilizer Association (IFA) and Yara (in-kind), and collaborates with CIMMYT and University of Nebraska-Lincoln. It runs from 2016-2021.

Email: info@cropnutrientgap.org

Internet: http://www.cropnutrientgap.org/

Authors of this report and contact details

Peter W. Mtakwa[1], Ndelilio A. Urio[1], A. P. Mtakwa[1], Frank Brentrup[2], Peter Assey[2], Marloes van Loon[3], Renske Hijbeek[3], Hein ten Berge[3], and Martin van Ittersum[3]

[1]Sokoine University of Agriculture, Tanzania
[2]Yara
[3]Wageningen University & Research

If you want to cite a report that originally was meant for use within the project only, please make sure you are allowed to disseminate or cite this report. If so, please cite as follows:

P.W. Mtakwa, N. A. Urio, A. P. Mtakwa, F. Brentrup, P. Assey, M.P. van Loon, R. Hijbeek, H.F.M. ten Berge and M.K. van Ittersum, 2020. D9593: Results from the Fertilizer demonstration experiment with maize at IOP Farm in Iringa, Tanzania in 2019, www.cropnutrientgap.org, 15 pages.

Table of contents

Summary

In 2019, an experiment was run at the IOP farm in Tanzania. Five nutrient management treatments were combined in a full factorial setup with two tillage options. The lowest maize yield was obtained under conventional tillage without fertilizer application, and the highest maize yield with reduced tillage and the highest NPK fertilizer level combined with micronutrients. This highest NKP fertilizer level targeted 70% of water-limited yield. Furthermore, it was shown that P and K were used more efficient under reduced tillage compared to conventional tillage, while there was no difference in N use efficiency between the two tillage options. In addition, a number of field visits was organized. From the six villages surrounding the farm a total of 120 farmers made at least 4 visits to the experiment once in every month between February and June. That brings the number of farmers that learned from the 2018 trial to 480+.

Keywords

Tanzania; experiment; nutrient management; tillage; maize; yields

1. Introduction

Large parts of land suitable for agriculture in Tanzania are currently not under cultivation, presenting both threats and opportunities. In places where agriculture is practised, yields are low because of inherent low soil fertility, low use of costly inputs and unpredictable weather (resulting in a very narrow planting window). As a result, actual farmers' yields are usually 20% or less of potential yields under rainfed conditions (yieldgap.org). A field experiment was set-up addressing farmers' dilemmas by introducing demonstrations on reduced tillage, and proper, efficient fertilization. Visits for farmers and stakeholders were organised.

The objectives of the (large-scale) experiment are: test fertilisation and tillage practices in maize and their potential to close the yield gap; analyse nutrient use efficiencies and other agro-environmental aspects (e.g. GHG emissions); and use the trial as demonstration and discussion object for farmers in the region.

2. Location

The experimental location is on the Ilula Orphan Program (IOP)'s Farm, Ilula, Iringa Region, in Tanzania (7°38'51.4"S 36°04'05.0"E) (Fig. 1). IOP is a non-governmental organization in Tanzania dealing with impact mitigation to: 1) determine the root cause and help to uproot the most vulnerable children (orphans from extremely poor families, children from poor single mothers or single fathers); 2) empower the elderly; 3) empower young mothers and the youth through training. IOP owns a modern commercial farm, named Farm for the Future Tanzania Ltd (FFF) that started operation in 2018, which is also used as a training centre. It is a registered Farm aimed to generate income, empower single mothers through training (socio-economic and agriculture) and encourage school children (kindergarten all the way to secondary school) to develop love for the agriculture by providing visits and activities that will stimulate them to grow with a positive image of this number 1 employer in Tanzania. This trial experiment is part of the FFF.

Fig. 1 Map of Tanzania showing the experimental location

3. Trial lay-out

3.1. Trial set-up and treatments

Five nutrient management options were combined with two tillage options, resulting in ten different treatment combinations (Table 1). The trial has a split-plot design with tillage as main plots and the five fertilizer treatments as split plots. There are four replications of each treatment with a plot size of 10.4 m by 10.8 m (16 rows at 65 cm, and 36 planting holes placed at 30 cm apart, resulting in a plant density of 5.13 plants/m^2). Net plot (harvesting) size is 9.75 m x 10.5 m, equivalent to 102.375 m^2. Liming was not required since former soil analysis showed an average pH of 5.5 (4.6-6.3).

Table 1. Experimental treatments, which are a combination of the nutrient management and tillage options.

Treatment	Tillage	Compost applied	Nutrient application rates (kg nutrient/ha)					
			N	P_2O_5	K_2O	MgO	S	Zn
CT-F1	Conventional	No	0	0	0	0	0	0
CT-F2	Conventional	No	98	42	42	0	0	0
CT-F3	Conventional	No	98	43	42	9	13	1
CT-F4	Conventional	Yes	49	21	21	0	0	0
CT-F5	Conventional	No	0	42	42	0	0	0
RT-F1	Reduced	No	0	0	0	0	0	0
RT-F2	Reduced	No	98	42	42	0	0	0
RT-F3	Reduced	No	98	43	42	9	13	1
RT-F4	Reduced	Yes	49	21	21	0	0	0
CT-F5	Reduced	No	0	42	42	0	0	0

[1]Yw is the water-limited potential yield, and is estimated as 7.0 t/ha, the yield target is 70% of Yw which is 4.9 t/ha (85% dry matter).

3.2. Fertilizer treatments

The fertilizer treatments include a control treatment (F1) without any fertilizer application, which is required to assess crop response to fertilizer application and to calculate fertilizer use efficiency. The unfertilized control is also close to prevailing farmer practice. The F2 and F3 treatments supply nitrogen (N), phosphorus (P), and potassium (K) at a rate that could accommodate NPK uptake of maize at 70% of its water-limited yield potential identified for the site at IOP Farm. Based a combination of both the Global Yield Gap Atlas (GYGA) and expert judgement, the water-limited yield potential was estimated at 7 t maize grain per ha (at 85% dry matter), i.e. resulting in a target yield of 4.9 t/ha maize yield (70% of the yield potential). We assumed 20 kg N uptake per tonne of grain produced, which resulted in 98 kg N/ha application rate (Table 1). P and K rates were determined by the N-P-K ratio of the recommended fertilizer product YaraMila Cereal (used in F3). The F3 treatment investigates the potential benefit of applying the additional plant nutrients sulphur (S), magnesium (Mg) and zinc (Zn), knowing from previous soil analysis that these nutrients are frequently in deficiency. This treatment also represents the current Yara recommendation for maize grown in the Southern Highlands of Tanzania. The fourth fertilizer treatment (F4) includes the use of organic material (composted manure). This treatment assumes that farmers can afford at least half the recommended rate of industrial fertilizer and supplement it with the readily available compost manure. Further, it is assumes that after a few years' of application the manure should be able to replace 50% of the mineral fertilizer and lead to better soil physical conditions (i.e., increased Soil Organic Matter content, a very important soil attribute that is generally low in soils of the tropics). The fifth fertilizer treatment (F5) includes the supply of P and K only; this treatment is required to assess crop response to N fertilizer and to calculate N use efficiency.

The agronomic N use efficiency, N-AE, is the additional grain yield per kg N applied when correcting for the P and K applied (by comparing yields in the NPK treatment [F3] with yields in the PK treatment [F5], divided by the N applied).

$$N\text{-}AE = \frac{yield_{NPK} - yield_{PK}}{N_{applied}} \qquad (1)$$

The fertilizer use efficiency, NPK-AE, is the additional grain yield per kg N applied when including yield effects from P and K (by comparing yields in the NPK treatment [F3] with yields in the control treatment [F1], divided by the N applied).

$$NPK\text{-}AE = \frac{yield_{NPK} - yield_{control}}{N_{applied}} \qquad (2)$$

By subtracting the N-AE from the NPK-AE, the P and K fertiliser effects on yields are revealed.

3.3. Tillage treatments

All fertilizer treatments were combined with two different tillage practices, (1) conventional (CT; Fig. 2a) and (2) reduced tillage (RT; Fig. 2b). Conventional tillage represents common farmer's practice. At IOP Farm this means using a disc plough on the whole field. Reduced (or conservation) tillage means for this experiment using a ripper instead of a disc plough, and ploughing only the planting lines, leaving the remainder of the field untouched. This minimizes soil exposed to the vagaries of weather (reduces erosion), minimizes destruction of soil flora and fauna (hence encouraging a richer biodiversity). It ensures exact placement of fertilizer (in the furrow), and hence better use of the fertilizer by the plant, leading to, presumably, bigger harvests. It reduces the use of fossil fuel, hence a cleaner environment and cheaper farming operations (fewer runs than when whole field is tilled). Ripping results in better water harvesting and storage due to less soil exposure (no inversion/turning of the soil) and the deep strips that are formed collect and store more water. In the long run, this might enable minimum use of herbicides and tillage.

Fig. 2 a) Conventional tillage through disc ploughing, and b) reduced tillage through ripping

4. Activities and measurements

At the start of the experiment land preparation (tillage), trial set up, seeding, herbicide application, application of well decomposed manure and fertilizer activities were done (Fig. 3). In a second stage of the experiment the following management activities were performed: weeding, fertilizer top dressing, herbicide application. In a third stage of the experiment the following management activities were performed: final top dressing, pesticide application. Finally, the maize plants in the trial experiment were harvested.

Fig. 3 a) Laying out planting hole markers, b) Fertilizer application prior to mixing with soil, followed by seed placement.

5. Results

Reduced tillage (RT) resulted on average in a 13% higher yield compared to conventional tillage (CT), but this difference was not significant (*P*=0.37). However, there were significant differences between the fertilizer treatments. If no fertilizer was added (F1) or if only P and K was added (F5) this resulted in significant lower yields compared to the addition of NPK to target 70% of Yw (both the treatment with (F3) and without micronutrients (F2)) (Fig. 5).

Fig. 4 Photos from some of the different experimental treatments (F1 – F5 respectively) 2.5 months after emergence. See Table 1 for explanation on the treatments.

Overall, the lowest maize yield was obtained under conventional tillage without fertilizer application (CT-F1), and the highest with reduced tillage and NPK fertilizer to target 70% of Yw and the addition of micronutrients (RT-F3) (Fig. 5). Interestingly, reduced tillage resulted in an increase of 1.5 tonnes per ha when no fertiliser was applied (F1). Reduced tillage did not significantly increase maize yield when fertiliser was applied (F2 to F4). The effect of secondary nutrients (here Mg, S, Zn combined) was not significant.

The amount of fertilizer applied was aimed to target 70% of Yw, but in all cases it resulted in yields which were higher than the target, and in several cases ca. 100% of Yw was reached (Fig. 5). The average agronomic N use efficiency (N-AE, Eq. 1) was lower than what beforehand was targeted. Namely, the average N-AE were 30.0 (21.8 – 40.0, lower and upper range), and 39.1 (25.4 – 61.8, lower and upper range) under conventional tillage and reduced tillage respectively compared to the targeted N-AE of 50 kg yield/kg N (blue line Fig. 6a). However, the observed values are still high compared to the current average N-AE in sub-Saharan Africa of 14.3 kg yield/kg N (Ten Berge et al., 2019; red line Fig. 6a). Furthermore, this experiment shows that it seems possible to obtain N-AE values which are relatively close by the optimum of 52 kg yield/kg N (green line Fig. 6a).

Results show that no significant differences in N-AE were observed between reduced and conventional tillage (P=0.36) (Fig. 6a) and also not in fertilizer use efficiency (P=0.09) (NPK-AE, Eq. 2; Fig. 6b). However, the yield effect from P and K fertiliser were larger under conventional tillage (P=0.04) (NPK-AE – N-AE; Fig. 6c). This suggests that under reduced tillage more soil P and K was available to the maize crop and therefore the crop was less reliant on the PK fertilisation.

The experiment is repeated with the same set-up in 2020.

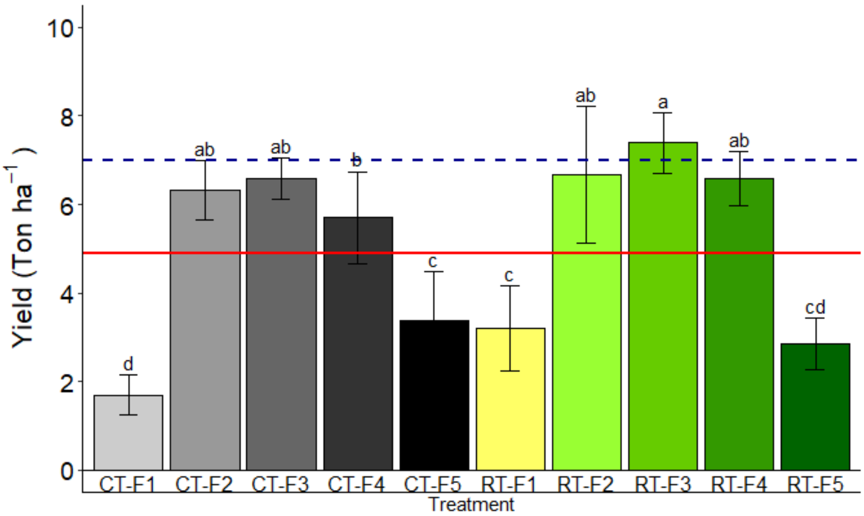

Fig. 5 Average maize yield (at 85% dry matter) with standard deviation for the different treatments (see Table 1 for treatment explanations). Bars labelled with different letters indicate significant differences in yield between the treatments (P<0.05). Blue dashed line indicates the estimated water-limited potential yield, and the red continuous line is 70% of the water-limited yield.

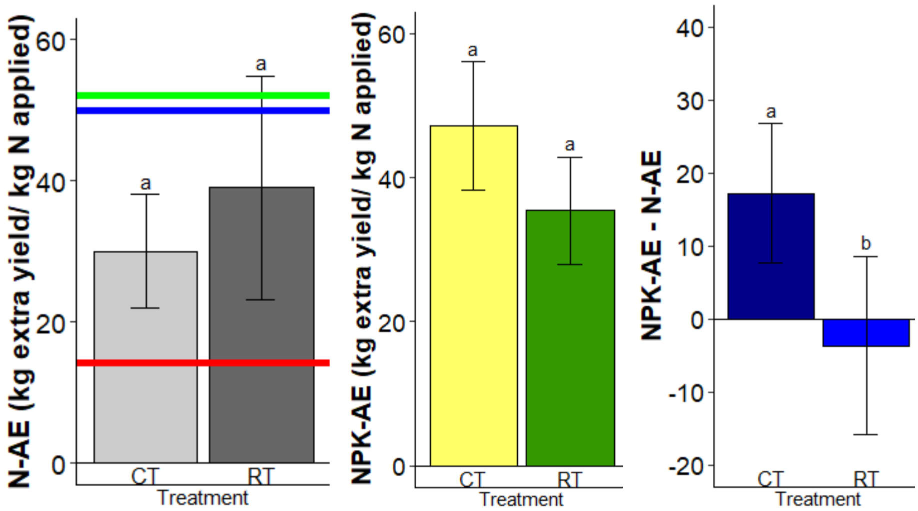

Fig. 6 A) Agronomic N use efficiency (N-AE, i.e., yield of treatment F3 – yield of treatment F5 / N applied at treatment F3; see Table 1 for treatment explanations), red line is the current average N-AE in sub-Saharan Africa (Ten Berge et al., 2019), blue line is the assumed N-AE, and green line is the estimated optimum N-AE (Ten Berge et al., 2019); b) fertilizer use efficiency (NPK-AE, i.e., yield of treatment F3 – yield of treatment F1 / N applied at treatment F3); c) PK efficiency (i.e., NPK-AE – N-AE) for conventional tillage (CT) and reduced tillage (RT) with standard deviation. Bars labelled with different letters indicate significant differences between the treatments (P<0.05).

6. Communication and outreach

Combining commercial farming and training is a completely new approach in Tanzania. Involving children is very much hailed by the regional authorities as the right way forward. The experiment at the IOP farm supports creating a knowledge base on nutrient management and tillage options to improve maize yields.

A number of field visits by farmers were organised to the experiment in 2019 (Fig. 7). Village leaders were requested to come with at least 20 farmers each, divided equally between male and female (it actually meant 10 household members, a man and his wife to consolidate learning) to an inaugural meeting where they were introduced to the IOP and Farm for the Future philosophy, then to the tillage-fertilizer planned trial. During the trial life, these farmers, plus any other farmer interested in what was going on, were taken through the Trial by the IOP Agricultural Officer, Mrs Tulia MKWAMA as well as by FFF Farm Manager Ms Grace Kimonge. Six villages surrounded the farm, hence a total of 120 farmers made at least 4 visits to the farm, once every month between February and June. That brings the number of farmers that learned from the trial last season to 480+.

Fig. 7 Photos at trial site on Farmers Field day, 24 April 2019 of a) sharing of research findings; b) gathering of farmers, village leaders, extension agents, scientists and suppliers of agro-chemicals; c) addressing members of the media.

Acknowledgements

Our thanks goes IOP for providing the much needed on-site supervision of the Trial and arranging for labour. Farm for the Future supported and advertised this Trial very much; they also adopted the complete dose regime that has proven so successful even during the first year of maize production in their farm. During the second year being of the Trial, FFF have taken up supervision of the Trial through the Company's farm Manager, Ms Grace Kimonge: we greatly thank them. Towards the end of the second season, we receive services of final year BSc (Agronomy) students. They helped with harvesting and, later, root depth analysis. Their contribution is very much appreciated. The picture will not be complete without thanking the clients and users of the results from this Trial: Regional Commissioner, District Commissioner, the Village Leaders, Farmers and Single mothers. To them we say *asante sana* for patronizing us.

Crop Nutrient Gap Project

Annual Report

Version Final_date

Partners involved in the Crop Nutrient Gap Project

- Wageningen University and Research
- International Fertilizer Association
- University of Nebraska Lincoln
- Yara
- CIMMYT
- IOP
- FFF
- Sokoine University of Agriculture