# Critical analysis of tillage practices with fertility levels in maize and populations in beans as adaptation measures to climate change to enhance food security at Kabete

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**Abstract**

Trials were carried out in 2012/2013 short and 2013 long seasons at Kabete site representing a warm and wet environment in Kenya to determine, the appropriateness of combining fertilizer levels for maize and population levels with tied ridges for beans, as adaptation measures under changing climate. The maize experiment consisted of three fertilizer levels of 0, 20 and 40 kg/ha N while the bean experiment had three spacings of 12, 15 and 20 cm in a split plot design. The experiments were replicated thrice and consisted of conventional tillage and tied ridges as main plots representing the two soil water management practices while the three soil fertility levels (in maize N0, N20 and N40) or spacing options (12, 15 and 20cm) were sub plots in a Completely Randomized Block Design. The ridges were tied at intervals of 1 m and spaced at recommended crop spacings (i.e. 75cm for maize and 45cm for beans) and the crop planted on the slope of the ridge in 6 by 5 m plots. Basal phosphate ($P_20_{5)}$ fertilizer in the form of Triple Superphosphate was applied at planting time at the rate of 40kg/ha. Nitrogen in the form of Calcium Ammonium Nitrate was applied at 20 Kg/ha in the 20 and 40 N treatments at planting and further 20kg/ha N top dressed in the 40 treatment level. Harvesting was done at physiological maturity of grain which was air dried. Statistical analysis was done of the treatments and comparisons done of the adaptation advantages of the treatments. Tied ridging increased maize yields at the medium fertilizer level of 20 (+5.22%) but were negative under both zero (-15.56%) and 40 kg/ha application of fertilizers (-5.42%). In the short season, increased bean spacing from 12 to 20 decreased yields under normal (-13.6%) and tied ridges (-37.3%) but remained higher at populations of 12 and 15. In the long season increasing bean population from spacing of 12 cm to 20 had no advantage and under tied ridging compared to normal tillage. Tied ridging as a climate change adaptive measure should not be instituted as a blanket recommendation across rainfall regimes, crops, fertilization levels or plant populations and is more advantageous in drier seasons.

## Introduction

It is now acknowledged that climate change would impact negatively on agricultural production through reduction of crop yields especially under subsistence farming in developing countries where impacts on food security can be devastating (Bochiolo *et al,* 2013). Climate change already adversely impacts on 175.4 million ha of rain-fed agriculture accounting for some 440.8 MT of production in sub Saharan Africa alone (Calzadilla, *et al*, 2008; Ewbank, 2012). It is also reported that there will be an increment of global temperatures but it is not so clear whether or not rainfall will decrease or increase or in which areas. Various scenarios have been developed to attempt to understand the impacts of these climate change possibilities (Lobell and Burke, 2008; Onyango *et al*, 2012). Experience has also shown that these possible impacts can be dealt with by integrating a wide range of adaptation strategies especially into national development planning (Parry *et al*, 2007; Deressa *et al*, 2008). Some positive adaptation measures reported include seed choices and planting dates for the likely changes in climatic conditions to which significant increases in yields have been attributed (Campbell *et al*, 2009). Given that small-scale farmers globally use 60 per cent of the world's land to produce half the world's food (Ewbank, 2012), introducing adaptive capacity to prevent eminent hunger and reduce poverty in the face of impeding climate change is pertinent (Van Ardenne-van *et al*, 2002).

In Kenya effectiveness of tillage practices to improve rainfall water utilization is significantly influenced by soil and climatic conditions Sijali and Kamoni (2005). Tied ridges can yield more maize crop dry matter (1.18 Mg/ha) than flat tillage (1.04Mg/ha) when seasonal rainfall is 222mm but dry matter under tied ridges (0.69Mg/ha) was 28% less than flat tillage when the rainfall was 144mm (Sijali and Kamoni, 2005). It is hence important to test these practices under a variation of soil and climatic conditions to determine their relative advantages across various conditions. In-situ soil moisture conservation entails capturing rainwater and retaining it in the soil for in-situ plant utilization for growth and increase in grain and biomass yield. Gichangi *et al* (2007) proposed that whatever in-situ rainwater conservation technologies are used, manure should be an integral part of the technology for increased soil moisture conservation and utilization by crops for increased crop production and food security in eastern Kenya. Kathuli *et al*, (2010) reported that tied ridging when used with fertilizer, manure or their combination has potential to increase crop yields by up to 100-300%. These increments have been explained to arise from use of fertilizers and or manures with in-situ soil moisture conservation through improved water use efficiency by crops planted in this semi-arid region of eastern Kenya (Itabari *et al*, 2004; Gichangi *et al*, 2007). Manure has also been shown to increase soil moisture profile irrespective of whether it is used with in-situ soil moisture conservation technology or otherwise (Gichangi *et al*, 2007). This analysis attempts to outline salient adaptation strategies of maize under fertilizers and bean populations at Kabete Kenya.

## Materials and methods

### *Area of study*

Experiments were carried out at Kabete Campus Field station which represents a warm and wet agro-ecological zone (UM3) and lies between 36$^{O}$ 44, E 01$^{O}$ 15 S co-ordinates at an altitude of 985 meters above mean sea level. The site lies on a humic nitisol receiving about 970 mm of rainfall, has a mean annual temperature of 18.2$^{o}$ C and a bimodal pattern of rainfall with two cropping seasons per year.

### *Experimental layout*

The first experiment was laid in a split-split plot design layout consisting of two soil water management practices and (W0= Normal tillage and W1= tied ridges) as main plots, three plant fertilizer levels (0= No fertiliser, 20=20 kg N/ha and 40=40 kg N/ha) and as the sub-plots. Maize *(Zea mays)* variety DK8031 was used as the test crop. The second experiment had also the two soil and water management practices (W0= Normal tillage and W1= tied ridges) as main plots, three plant densities (1=12cm, 2=15cm and 3=20cm) as the sub plots with beans *(Phaseolus vulgaris)* (KK8 variety) as the test crop. The treatments in both experiments were in 6 x 5 m plots and were replicated three times. The results presented below are of grain yield attributes from 1$^{st}$ season (2012 long rains) and 2$^{nd}$ season (2012/2013 short rains).

## Results and discussion

### *Fertility and ridging responses in maize*

In the short rainy season (i.e 2012/2013) tied ridges had +8.18% and +5.68% increments in maize yields under zero and 20kg/ha N applications but reduced yields by +9.06% under 40kg/ha applications at Kabete. See Figure 1. Generally however, the fertilizer levels also progressively increased maize yields from zero application to 40 kg/ha. Comparing the two tillage practices tied ridging had higher yields at the medium fertilizer levels of 20 (+5.22%) but were negative under both zero (-15.56%) and 40 kg/ha application of fertilizers (-5.42%). The highest positive change in maize yields occurred with 20 kg/ha N application. See Figure 1.

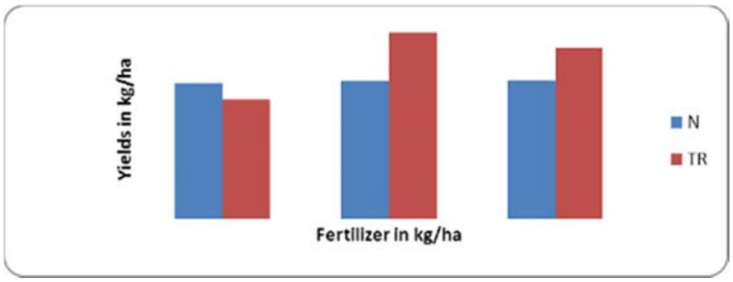


**Figure 1:** Maize responses in second season 2012/2013

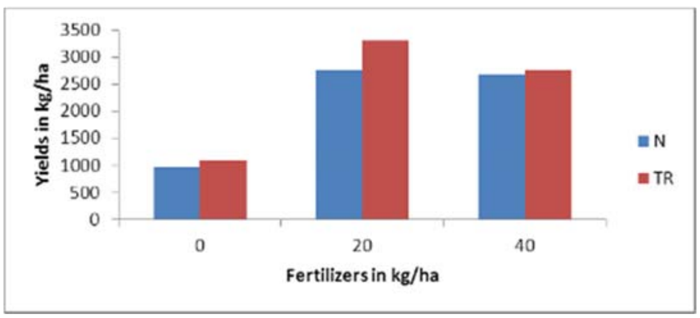


**Figure 2 :** Maize responses in the first season 2013

During the first season 2013 maize yields progressively increased (i.e. 1.9%) with increasing fertilizers rates under normal tillage. See Figure 2. Under tied ridging however increasing fertilizer levels from 0 to 20 raised the maize yields by 55% but when the fertilizer levels were further raised to 40 the yields decreased by 6.5%. The best yields under tied ridges were therefore obtained with 20 kg/ha application of fertilizers.

Normal tillage had relatively lower yields even with the 40 kg/ha fertilizer levels and was relatively advantageous to tied ridging when no fertilizers were applied. There is therefore no need to invest in labour constructing tied ridges if no fertilizers are to be applied as evident in both seasons. It is also unnecessary to increase fertilizer levels to 40kg/ha especially with tied ridging which would yield even less than a lower application. Increment in yields under tied ridges can be explained to be arising from increased plant available moisture content as was also reported by Miriti *et al.,* (2012). Kathuli *et al* (2010) has also reported general increments in yields of maize in semi arid areas of Kenya.

***Population and ridging responses in beans***

In the short rains (i.e. 2012-2013) increasing bean populations from a spacing of 12 to 20 decreased their yields progressively both under normal (-13.6%) and tied ridges (-37.3%) although yields under tied ridges were higher at populations of 12 and 15. See Figure 3. Tied ridging was therefore only slightly advantageous under populations of 12 and 15 but was actually disadvantageous at populations of 20.

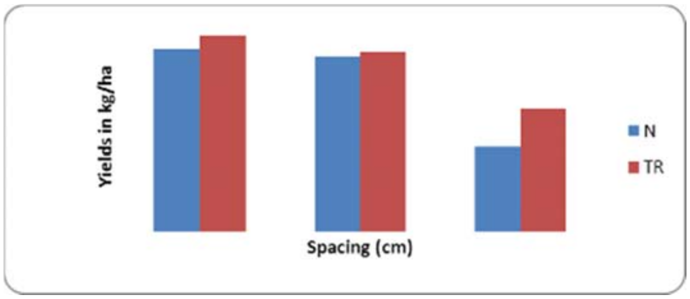


**Figure 3:** Bean responses in second season 2012/2013

During the 2013 long rains normal tillage consistently yielded better (21.5%) than tied ridges under all the three plant populations. See Figure 4. Under tied ridging however increasing the population from spacing of 12 to 15 increased the yields by 20.5% before dropping by 18.1% when the spacing was increased to 20. Increasing the population from spacing of 12 cm to 20 clearly had no advantage and under normal tillage and even appeared to be reducing the yields.

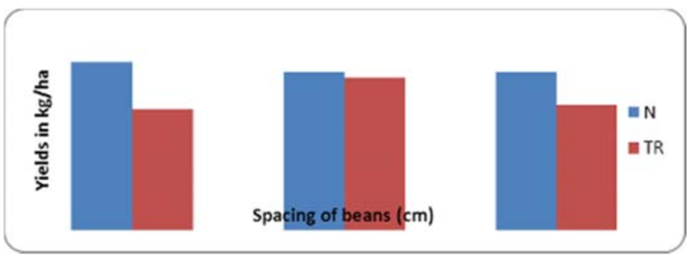


**Figure 4:** Beans responses at Kabete first season 2013

Since the March-June rainfall has consistently higher rainfall there appears that there would be no advantage in conserving extra moisture for beans at Kabete. However under the drier season (e.g. November-December short rains) a clear advantage is observed under tied ridging.

**Conclusions**

- The tied ridging as a climate change adaptation measure should only be instituted with caution and is dependent on crop and rainfall regime.
- Under maize tied ridges should be instituted with medium (20kg/ha) fertilizer applications otherwise further increments in fertilizer rates alone would appropriately improve yields especially in the drier seasons without institution of tied ridges
- Bean yields would be enhanced under lower populations if tied ridges are instituted in the drier seasons but decreasing the population (i.e. spacing of 20) has no advantage. With adequate rainfall (i.e. in the long season) it would be unnecessary to institute tied ridges with any bean population

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**References**

Bochiolo, D., Nana, E and Soncini, (2013). Impact of climate scenarios on crop yields and water footprints of maize in the Po valley, Italy. Agricultural water management, 116 (50-60).

Campbell, A, Kapos, V., Scharlemann, JPS, Bubb, P, Chenery, A., Coad, L. Dickson, B. Donswald, N. Khan, M.S.I, Kershaw, F. Rashid, M. (2009), Review of literature on the links between biodiversity and climate change: Impacts, Adaptation and mitigation. Secretariat of the Convention on biological diversity, Montreal. Technical Series no. 42, UNEP 124 pages.

Calzadilla, A., Zhu, T., Rehdanz K., Tol R.S.J.and Ringler, C., (2008). Economywide impacts of climate change on agriculture in sub Saharan Africa.IFPRI Research Brief 15-15.Washington.

Deressa, T.T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yesuf, (2008). Analysis of the determinants of farmers' choices of adaptation. Methods and perceptions of climate change in the Nile basin of Ethiopia. IFPRI Discussion paper. Washington DC.

Ewbank, R., 2012, Forecasts benefit farmers at risk from weather extremes, Climate and Development Knowledge Network.

Gichangi E., E. Njiru, J. Itabari, J. Wambua, J. Maina and A. Karuku (2007). Assessment of improved soil fertility and water harvesting technologies through community based on-farm trials in the ASALs of Kenya. In: A. Batiano (eds). Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities. pp 759-765. 2007 Springer. 10.1007/798-1-4020-5760-1.71.

Miriti, J., G. Kironchi, A.O. Esilaba, L. Heng, C.K.K. Gachene and D. M. Mwangi: Yield and water use efficiencies for maize and cowpeas as affected by tillage and cropping systems in semi arid eastern Kenya. Agricultural water mangerment. 115 (2012) 148-155.

Onyango J.W., J.M. Miriti, W.E.A. Nganyi, J. W. Wamuogo (2012). Assessment of rainfall variability and its implication on agriculture in two locations in Kenya. Paper presented at the 13$^{th}$ Biennial Conference held at KARI headquarters between October 14$^{th}$ 2012.

Sijali, V.I. and Kamoni, P.T., 2005. Optimisation of water and nutrient use in rain-fed semi arid farming through integrated soil-water-nutrient management practices. In: Nutrient and water management practices for increasing crop production in arid/semi-arid areas. Proceedings of Coordinated research projects by IAEA. Pp 204-216.

Lobell D.B. and Burke M.D. (2008). Why are agricultural impacts of climate change so uncertain? The importance of temperature relative to precipitation. *Environ. Res. Lett.* 3 (3), 034007.

Parry M.L., Canziani, O.F, Palutikof, J.P. van der Linden, P.J. and Hansen C. E. (Eds), 2007, Climate change: Impacts, Adaptation and Vulnerability. Contributions of the working group II of the 4$^{th}$ Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Itabari, J.K., Nguluu, S.N., Gichangi, E.M., Karuku, A.M., Njiru, E.N., Wambua, J.M., Maina, J.N. and Gachimbi, L.N. (2004). Managing Land and Water Resources for Sustainable Crop Production in Dry Areas. A case study of small-scale farms in semi-arid areas of Eastern, Central, and Rift Valley Provinces of Kenya. In: Crissman, L. (Eds.) Agricultural Research and Development for Sustainable Resource Management and Food Security in Kenya. *In*: Proceedings of End of Programme Conference, KARI, 11-12 November 2003. pp. 31-42.

Kathuli P. and J.K. Itabari., (2010). In-situ soil moisture conservation: utilization and management of rainwater for crop production in the arid and semi-arid lands of Kenya, KARI-Katumani, Box 340-90100, Machakos. Email:peterkathuli@yahoo.com.

Van Ardenne-van A, H., Beun, H., Brown M.M., Tadao, C. Johnson, D.J., Kabbaj O,. Nielson, P., Topfer, K., Wieizorel-Zeul, H and Zhang, S. (2002). Poverty and climate change: Reducing vulnerability of the poor through adaptation. Report delivered to the 8th Conference of the UNFCC in New Delhi. Collaboration report by Asian Development Bank, DFID, Governments of Netherlands and Germany, EU, OECD, UNDP, UNEP and World Bank.