#7507 VALIDATION OF CLIMATE SMART AGRICULTURAL TECHNOLOGIES FOR IMPROVED CROP YIELDS IN SEMI-ARID LANDS OF KENYA

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ABSTRACT

Kenya's Vision 2030 economic strategy identifies agriculture as one of the key sectors to drive the Country's economy. However, the agricultural sector faces various challenges. For instance, the sector is predominantly rain-fed and 80% of the land area is arid and semi-arid (ASALs). Due to challenges associated with rain-fed agriculture, the ASALs have the lowest development indicators and the highest poverty incidence levels. The Kenya Cereals Enhancement Programme – Climate Resilient Agricultural Livelihoods (KCEP-CRAL) tested and validated several agricultural technologies with potential to improve crop production in Kenya. This was achieved through establishment of 'Mother and Baby' Climate Smart Agriculture (CSA) trials for soil and crop management in eight Counties in Eastern and Coastal regions. These Counties included, Embu, Tharaka-Nithi, Kitui, Machakos, Makueni, Kilifi, Kwale and Taita-Taveta. The trials were established on station and on-farm during the October-November-December (OND) season of 2016 (for Eastern region and Taita-Taveta) and May 2018 (March-April-May (MAM) season for Kwale and Kilifi Counties. The tested CSA technologies were those of Conservation Agriculture (CA), Integrated Soil Fertility Management (ISFM), fertilizer source/efficacy, nitrogen, phosphorus, potassium, sulphur and zinc-based fertilizers. The test crops included cereals (maize, sorghum and millet) and pulses (beans, green grams, cowpeas and pigeon peas). In addition, the project conducted validation trials on push-pull technologies (PPT) for control of Fall Army Worms (FAW). The crops were tested for their performance, adaptability and acceptability in these environments. Results from soil characterization and field trials showed that organic carbon, nitrogen, phosphorus, sulphur and zinc were the most limiting nutrients in most of the counties. The soil amendments supplying the above listed limited nutrients were either organic, inorganic or/and organic inorganic combination sources coupled with appropriate crop varieties and soil and water management practices. The cereal and legume crop yields increased by at least 50-100 percent depending on the agro-ecological zone, crop type and ISFM technologies. It was concluded that farm-specific characterizations were important towards determining levels of farm/catchment specific application of both macro- and/or micro-nutrients for improved land and crop productivity. The study recommended adoption of sustainable farm specific management strategies to improve soil water, fertilizers and labour use efficiencies in the Kenyan ASALs.

Keywords: arid and semi-arid lands; macro and micronutrients; climate resilient agriculture; inputs use efficiency

INTRODUCTION

Agricultural sector is not only the driver of Kenyan economy but also the means of livelihood for over 80% of the rural Kenyans population. Indeed, the Kenya's Vision 2030 economic strategy identifies agriculture as one of the key sectors to drive the Country's economy. However, the agricultural sector faces a myriad of challenges related to aridity which characterizes over 80% of the total land area. These are compounded by rain-fed agriculture in Kenya which over the years has failed to adequately support crops to produce high yields. Smallholder farmers who account for about 80% of the country's population use inorganic fertilizers in combination with organic resources. Cereal and legume crop yield gaps are large in the smallholder farming systems but there is a potential of closing them through adoption of improved crop varieties and sustainable cropping systems. Continuous use of unbalanced inorganic fertilizers without addition of organics has led to increase in soil acidity, nutrient mining and decline in soil organic matter. In addition, rainfall variability resulting from climate change has negatively affected agricultural productivity. As one of the climate smart agriculture (CSA) remedies, Integrated Soil Fertility Management (ISFM) which also embraces adherence to conservation agriculture practices offer the best options for improving soil fertility and consequently the crop yields within and beyond the Kenyan ASALs. Based on the above background, a study was conducted in 8 Counties in Upper Eastern, Lower Eastern and Coastal regions to validate the benefits of embracing CSA principles and practices on soil and crop productivity in the selected sites and counties.

MATERIALS AND METHODS

For almost five years (2016 to 2020), the Kenya Cereals Enhancement Programme – Climate Resilient Agricultural Livelihoods (KCEP-CRAL) validated CSA technologies with potential to improve soil and crop production in the ASALs of Kenya. This was achieved through establishment and monitoring of on-station and on-farm trials following a "Mother and Baby approach in the Upper Eastern (Embu and Tharaka-Nithi Counties); Lower Eastern (Kitui, Machakos and Makueni Counties), and the Coastal regions (Taita-Taveta, Kilifi and Kwale Counties). A soil testing SMART (Soil analysis, Mapping, Recommendation and Transfer to farmers) approach was used as part of the novel procedures before and during seasonal establishment of the field trials. The first trials in the list of trials were the CA practices. These set of trials were made up of 24 treatments of residue management, tillage practices and crop varieties laid out in split-split plot randomized complete plot design. The second set of trials were based on ISFM treatments that included, a control, inorganic fertilizer at the recommended rates, farmyard manure (FYM) at the recommended rate and organic and inorganic fertilizer applied at half the recommended rates. The third set of trials were based on the fertilizer sources as defined in the 4R nutrient stewardship framework. This trial focused on the effect of the various fertilizer materials on crop productivity and had up to seven treatments composed of five inorganic fertilizers, farmyard manure and no input (control). The effect of potassium (K) based fertilizer on crop performance was the fourth trial in the list and tested the efficacy of 0, 40, 80, 120, 160 and 200 kg K_2O ha^{-1}. The K application treatments (including the 0 kg K_2O ha^{-1}) were provided with the recommended rates of N and P. The study had the effect of sulphur (S) based fertilizer as the fifth trial. The trials focused on the efficacy of 0, 10, 20, 30 and 40 kg S ha^{-1}. The five S application rates (including the 0 kg S ha^{-1}) were provided with the recommended rates of N and P. The sixth trial was of the effect of zinc (Zn) on crop yields. The trial had Zn applied at (0, 5, 10, 15 and 20 kg Zn ha^{-1}). The five Zn application rates (including the 0 kg Zn ha^{-1}) were provided with the recommended rates of N and P. The sixth treatment in the trial structure was absolute control (no inputs). The crops included in the trials were cereals (maize, sorghum and millet) and associated pulses (beans, green grams, cowpeas and pigeon peas) and push-pull technologies (PPT) to control Fall Army Worm (FAW). The crops were tested for their performance, adaptability and acceptability in these environments. Participatory Learning and Action Research (PLAR) was used during technology development, dissemination and capacity building of farmers, extension providers and other partners.

Data Collected and Analysis

The types of datasets that were collected included: crop performance during the growth period (phonological development) and crop yields (biomass and grains). Data sets were subjected to the analysis of variance (ANOVA) procedure (SAS, 2002). Differences between treatments means was separated using LSD at 5% level of significance.

RESULTS AND DISCUSSIONS

Effect of Conservation Agriculture (CA) on Crop Yields

It was evident that both cereal and legume crops grew vigorously under the Zai pit compared to those planted in zero and conventional tillage structures in all test crops, seasons and regions. Consequently, the crops under Zai gave significantly higher yields (shoot biomass and grains (Fig. 1). The higher yields under the CA based tillage practice (Zai pits) were attributed to the effect of in-situ water harvesting and conservation. Likewise, the pits concentrated together in-situ or applied ex-situ soil fertility nutrients for crop use. Additionally, the process of excavating the pits softened and also improves the soil depth allowing wider or/and deeper crop rooting for wider scavenging of limited plant growth resources. The three positive effects of Zai pits improved the crop resources use efficiency leading higher yields.

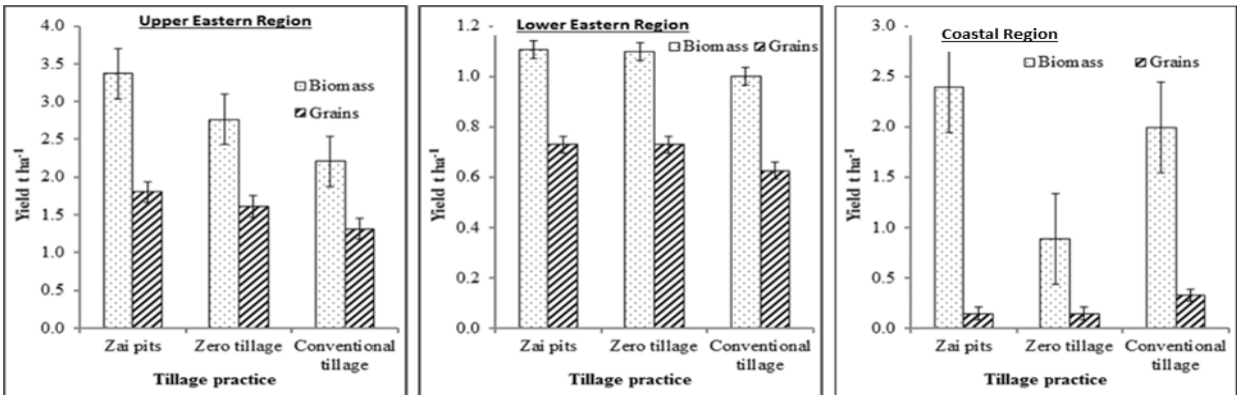

Figure 1. Effect of tillage practices on average green grams shoot biomass and grain yields

Effect of Integrated Soil Fertility Management (ISFM) on Crop Yields

In the Upper and lower Eastern, half Fertilizer (20 kg ha^{-1} N and P) and half manure (2.5 t ha^{-1}) (HMF) performed well for green grams. However, sorghum did better than green grams when full fertilizer rates 40 kg ha^{-1} N and P (FF) were applied across the regions (Fig. 2). Maize yields showed gradual increase in yields from no fertilizer to use of half manure plus half fertilizer then to full manure and the highest yield was achieved under full fertilizer application (Fig. 2.).

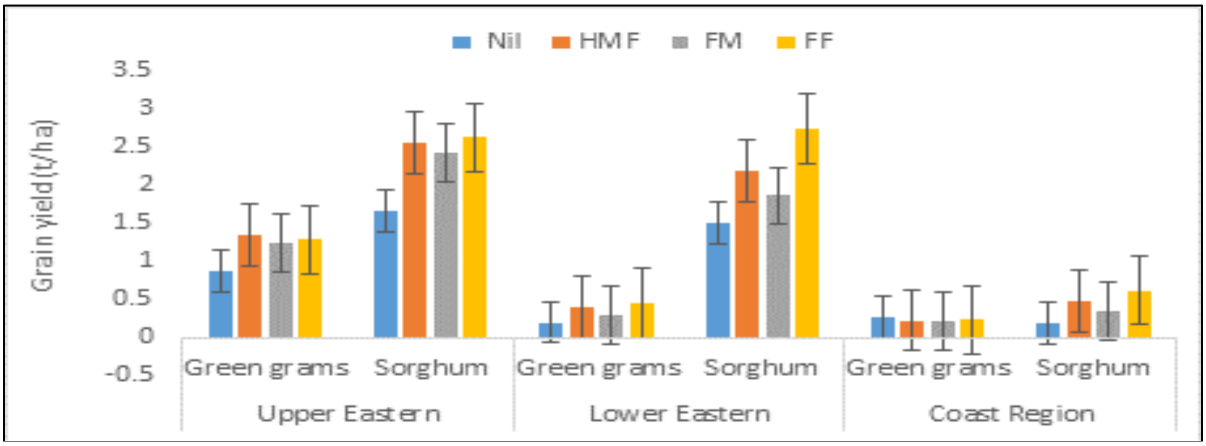

Figure 2. Green grams and sorghum response to integrated soil fertility management technologies

The Effect of Fertilizer Source and Efficacy on Crop Yields

Higher sorghum and millet grain and biomass yields were obtained with application of fertilizers compared to the nil application. Significant effects were found from plots treated with different fertilizer sources in Upper Eastern where Farmyard Manure (FYM), Diammonium Phosphate (DAP), MEA Mazao and Mavuno planting fertilizers gave the highest yields (Fig. 3). No significant differences were found in Lower Eastern and Coast regions. However, the increase in yields in plots treated with fertilizers from different sources indicated the need for fertilizer application in the three regions. The importance of FYM is shown by the significantly higher yields obtained from the treatment in Upper Eastern.

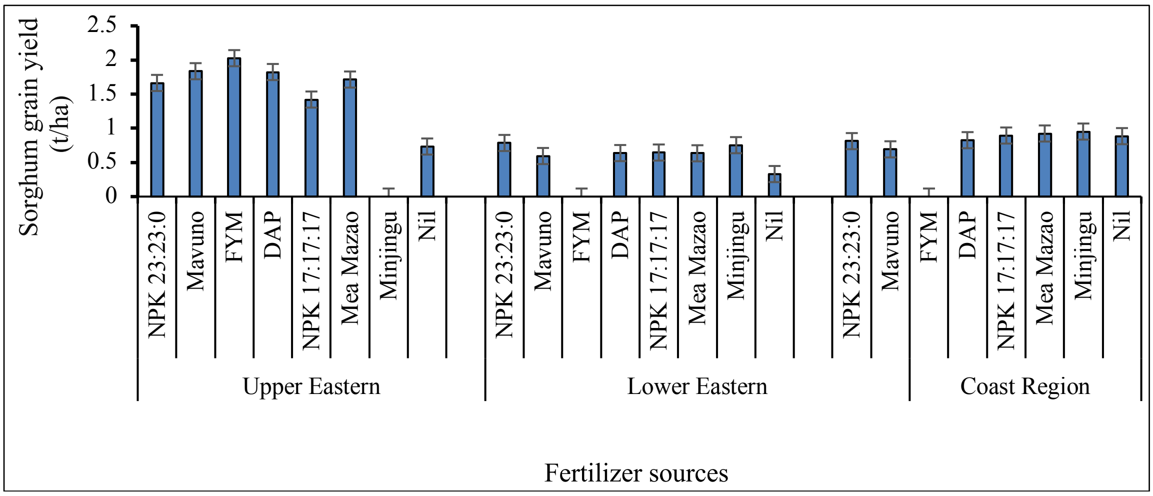

Figure 3. The effect of different fertilizer sources on sorghum yields in Kenya

The Effect of Potassium Fertilizers on Crop Yields

Application of potassium at 80 kg ha^{-1} had the highest millet yield but was not significantly different ($P<0.05$) from 40 kg ha^{-1} and no application of K (Fig. 4). Under sorghum, the highest yield response was recorded at 40 kg K ha^{-1} across the regions which was significantly different ($P<0.05$) from the other higher K fertilizer rates (Fig. 4). On average, the yields of millet, sorghum, maize and cowpeas highest at 40 kg K ha^{-1} (Fig. 4).

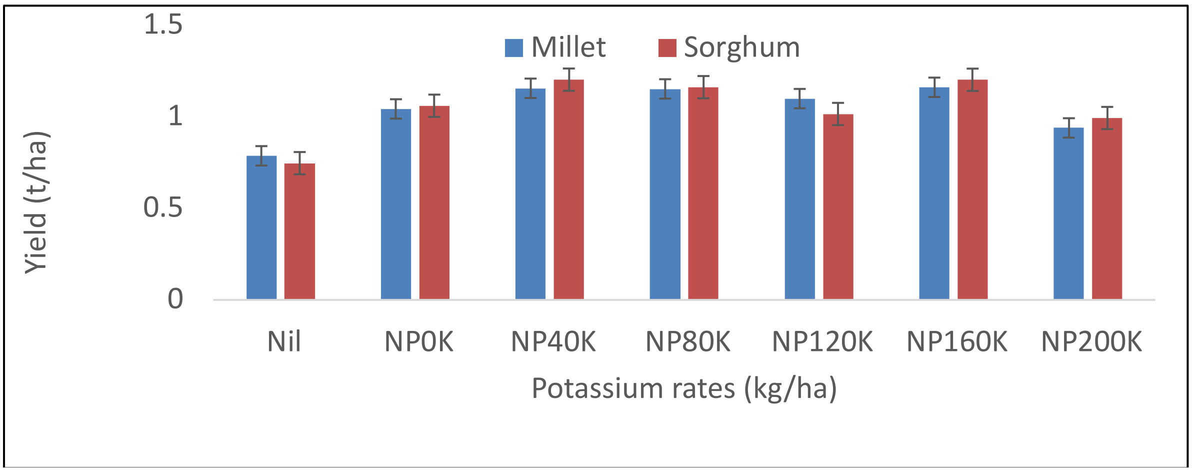

Figure 4. Average yields of millet and sorghum across Eastern and Coastal regions

The Effect of Sulphur and Zinc Fertilizers on Crop Production

A general trend showed that there was gradual sorghum, millet, maize and cowpea grain yield increases up to 20 kg S ha^{-1} followed by a decrease in yield on further addition of S. There was no significant response of cowpea and maize on sulphur application at the coast region. Similarly, there was no significant response of green grams, sorghum and maize to zinc fertilizers. Crop yields increased up to 5 kg Zn ha^{-1}. There is need for long-term trial management to confirm micronutrient responses.

Push-Pull Technologies (PPT)

In addition, the project conducted testing and validation on push-pull technologies (PPT) for control of Fall Army Worm (FAW). Brachiaria spp and Pannicum maximum grasses for wet and dry areas (respectively) attracted (pulled) fall armyworm from maize and sorghum while Clitoria and Lablab dolichos had the highest (40%) repelling (pushing) effect on the pest from the crops.

CONCLUSIONS

Soil characterization and field trials showed that organic carbon, nitrogen, phosphorus, sulphur and zinc were the most limiting nutrients in almost all the counties. The soil amendments supplying the above listed nutrients were either organic, inorganic or/and organic inorganic combination sources coupled with appropriate crop varieties and soil and water management practices. The cereal and legume crop yields increased by at least 50-100 percent depending on the agro ecological zone, crop type and relevant ISFM technologies. It was concluded that farm-specific characterizations were important in determining levels of farm/catchment specific application of both macro- and/or micro-nutrients for improved land and crop productivity. The study recommended the adoption of sustainable farm specific management strategies to improve soil water, fertilizers and labour use efficiencies in the Kenyan ASALs.

REFERENCES

FAO. 2018. Climate-smart agriculture training manual − A reference manual for agricultural extension agents. Rome. 106 pp.

Micheni A. 2015. Dynamics of Soil Properties and Crop Yields under Conservation Agriculture Practices in a Humic Nitisol, Eastern Kenya. Unpublished PhD Thesis, Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi.

SAS. 2002. Release 8.2, SAS Institute Inc., Cary, NC, USA.

UNDP. 2016. UNDP's Gender Equality Seal Certification Programme: Lessons Learned in Latin America. Women Deliver. http://womendeliver.

UNFCCC. 2007. Report on the workshop on climate related risks and extreme events. Note by the secretariat. FCCC/SBSTA/2007/7. UNFCCC. Bonn, Germany. 15 pp.

Vanlauwe B. Wendt J, Giller K, Corbeels M, Gerard B, et al. 2014. A fourth principle is required to define CA in SSA Africa: The appropriate use of fertilizer to enhance crop productivity. Field Crop Research 155: 10 – 13.

Wall PC, Thierfelder C, Ngwira A, Govaerts B, Nyagumbo I, et al. 2013. Conservation Agriculture in Eastern and Southern Africa. In Jat RA, Sahrawat KL, Kassam AH (eds.) Conservation Agriculture: Global Prospects and Challenges. CABI, Wallingford Oxfordshire OX10 8DE, UK.

World Bank. 2018. Kenya Agricultural Productivity Program (KAPP I and II). Independent Evaluation Group, Project Performance Assessment Report 133838. Washington, DC: World Bank.