# Agronomic technologies in maize and their adoption and diffusion in semi-arid central Rift Valley Ethiopia: agronomic and economic analyses

Agronomiske teknikker i mais og deres bruk og spredning i central Rift Valley i Etiopia: en agronomisk og økonomisk analyse

Philosophiae Doctor (PhD) Thesis

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## Abstract

This thesis evaluates the agronomic and economic responses to agricultural technologies in maize, identifies the agronomic technologies reaching farmers, and assesses their adoption and diffusion. The thesis consists of an introductory chapter and four papers.

Rainfall variability, poor soil quality, high cost of input technologies, an inefficient extension system, and low economic capacity are among the agro-ecological, institutional and socioeconomic constraints to increasing the productivity of maize in the central Rift Valley. Field experiments were conducted in the central Rift Valley of Ethiopia during the 2011/12 and 2012/13 cropping seasons to evaluate the agronomic and economic responses of tillage systems, fertilizer application systems and various packages of conservation agriculture, seed priming and fertilizer microdosing technologies in maize. A participatory research with the concept of 'learning by doing' and 'collaborative' and 'consultative' approaches for co-learning and co-innovation were used to enhance the participation of important stakeholders. To supplement the quantitative data, a case study was carried out to identify the agronomic technologies transferred to farmers, and to assess their adoption and diffusion. An adoption and diffusion theory was used as conceptual framework to study the adoption and diffusion. The data were collected through a series of key informant interviews, focus group discussions, and field observations.

Paper I evaluates the agronomic and economic responses of tillage and water conservation systems in maize. Conventional tillage and conservation agriculture were used as main plots whereas mulching, no mulching and planting basins were used as subplots. Results showed that agronomic and economic benefits of conservation agriculture were lower than those of conventional tillage under short-term practice. Conventional tillage had 13% to 20% higher grain yield (GY) than minimum tillage and 40% to 55% higher than zero tillage. Mulched treatments had 23% to 33% and 14% to 19% higher grain yield than no mulching and basins respectively. Conventional tillage had 28% and 89% higher labor productivity, and 6% and 60% higher gross margin (GM) than minimum tillage and zero tillage respectively. Mulching tended to improve volumetric soil moisture content and suppress weed density. However, due to the widespread practice of free grazing, this practice is not feasible on open fields. Yet, it can be practiced in the vicinity of homes where farmers traditionally fence smaller plots for growing early maturing maize varieties.

Paper II evaluates agronomic and economic benefits of fertilizers applied as microdosing and banding in maize. The treatments were: control without fertilizer, microdosing with the rate at 27 kg DAP ha$^{-1}$ + 27 kg urea ha$^{-1}$, 53 kg DAP ha$^{-1}$ + 53 kg urea ha$^{-1}$, and 80 kg DAP ha$^{-1}$ + 80 kg urea ha$^{-1}$; and banding of fertilizer with 100 kg DAP ha$^{-1}$ + 100 kg urea ha$^{-1}$. Small quantities of fertilizers applied as microdosing increased these benefits. Application of 27 kg DAP ha$^{-1}$ + 27 kg urea ha$^{-1}$ gave similar maize yields as the recommended rate of 100 kg DAP ha$^{-1}$ + 100 kg urea ha$^{-1}$ applied as banding. The 27 kg DAP ha$^{-1}$ + 27 kg urea ha$^{-1}$ increased the GY by 19%, 45% and 46% at Hawassa, Ziway and Melkassa respectively over farmer's practice. Its value cost ratio

varied from 7 to 11 whereas it varied from 2 to 3 in banding across sites. This shows that the lower fertilizer dose applied as microdosing is far less risky than the banding method. Similarly, its fertilizer use efficiency (kg grain $kg^{-1}$ fertilizer) varied between 23 and 34 compared to the banding treatment that had a fertilizer use efficiency varying between 7 and 8 across sites. Both value cost ratio and fertilizer use efficiency decreased with increasing fertilizer doses applied as microdosing. The lowest dose of fertilizer applied as microdosing gave the highest gross margin, fertilizer use efficiency and the least risk to fertilizer application. This shows that the application of this particular dose in maize may be an option for the poorer farmers who can only afford to buy small quantities of fertilizers. A fertilizer dose lower than this particular dose may also be an option. It needs further investigation.

Paper III examines different options of increasing maize yield by sequentially introducing minimum tillage and seed - priming, DAP fertilizer microdosing, surface mulching and urea fertilizer microdosing to the farmers' practice. There were five treatments or steps consisting of conventional tillage (farmers' practice as a control); minimum tillage + seed - priming, unfertilized (step 1); step 1 + microdosing 53 kg DAP $ha^{-1}$ (step 2); step 2 + 4 ton $ha^{-1}$ maize stover as mulch (step 3) and step 3 + 53 kg urea $ha^{-1}$ (step 4). Results showed that except at the lowest level, agronomic and economic benefits increased with increasing levels up the ladder. The second level increased GY by 19% to 22%, and GM by 12% to 19%; the third level increased GY by 25% to 35%, and GM 24% to 39%; the final level increased GY by 47% to 61%, and GM by 39% to 55%. The value cost ratio was above four even at the highest levels of inputs indicating that this level of intensification can be achieved at low risk. Likewise, the fertilizer use efficiency was quite high even at the highest level of inputs showing the efficacy of microdosing. This gives farmers different technology options for increasing the productivity of maize. This study also showed that with no mulching, minimum tillage in combination with seed - priming and fertilizer microdosing can be used to increase the productivity of maize. This could be an option for farmers lacking sufficient traction power even with free grazing.

Paper IV identifies the agronomic technologies transferred to farmers, and assesses their adoption and diffusion. Transferred technologies are mostly related to improved seeds, fertilizer application methods, and *in situ* rainwater-harvesting systems, which are also farmers' priorities of interventions. Technologies reach farmers through the national extension system, social networks or a combination of these. Use of improved maize and haricot bean varieties, the banding method of fertilizer application, row sowing, intercropping and traditional *in situ* rainwater-harvesting methods are among the technologies spreading recently. Most of the technologies transferred to farmers through the national extension system lack adequate information. Use of new hybrid maize and bean varieties has increased through the social networks although they have not been part of the national extension system. Technology adoption and diffusion is constrained by seasonal rainfall variability with recurrent dry spells and droughts, poor soil quality with poor fertility and water retention capacity, high prices for improved seed and fertilizer, and inappropriate fertilizer technologies. Subsidies, an efficient seed and fertilizer supply system, an adequate extension system, and provision of reliable seasonal agrometeorological information are lacking.

In conclusion, the technologies developed in this study are potentially low cost, low risk and agro-ecologically adaptable. They mostly appear to comply with farmers' interests and priorities and have positive prospects. They may be used separately or in combination to intensify the production of maize and improve farmers' income, food security and livelihood in the central Rift Valley in Ethiopia. It is still recommended that further studies based on long-term data and wider areas be done before integrating the technologies into the national extension system or social networks.