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Run-off water harvesting for dry spell mitigation in maize (*Zea mays* L.): results from on-farm research in semi-arid Kenya

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Abstract

Maize (*Zea mays* L.) yields obtained by small-holder farmers in semi-arid zones in sub-Sahara Africa (SSA) are often less than half of potential yields. Water deficit during critical crop growth stages together with low nutrient input interacts to reduce yields. Collection of surface run-off, which could be used as supplemental irrigation may prove beneficial in improving current small-holder farming system in SSA. This paper presents the results of an on-farm study of the effects of supplemental irrigation (SI) on maize yield in semi-arid Kenya. Surface run-off from a catchment of 2.7 ha was harvested in a hand-dug earth dam of 300 m^2. The water was supplied by gravity to mitigate dry spells in fertilized (SI30, SI80 kg N ha^{-1}) and non-fertilized (SI0 kg N ha^{-1}) maize. Treatments of SI were compared to non-irrigated treatments (NI80, NI30, NI0 kg N ha^{-1}). Rainfall varied, during the five seasons of study, from 196 to 564 mm. The volume of water harvested in the dam ranged between 1% and 4% of seasonal rainfall. The outtake for supplemental irrigation varied between 20 and 240 mm per season. Seepage losses accounted for 11 to 74% of harvested dam water. Lowest maize yields were in NI0, representing farmers' current practise. SI with fertilizer increased yields compared to non-irrigated and fertilised treatments (NI30, NI80) for low rainfall seasons (<300 mm). High rainfall seasons (>300 mm) resulted in no yield increase for SI compared to NI. Mean seasonal grain yield for SI and fertilizer (30 or 80 kg N ha^{-1}) of 1796 kg ha^{-1} was significantly higher ($P < 0.001$) than NI0 kg N ha^{-1} of 1319 kg ha^{-1}, and higher than SI0 kg N ha^{-1} and

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NI30 kg N ha^{-1} ($P < 0.01$). Lowest average rain and irrigation water use efficiency (RUE, kg grain mm^{-1} ha^{-1}) was for NI0 with RUE = 2.1, and highest for SI30 with RUE = 4.1. Water harvesting of surface run-off added as SI resulted in improved maize yields as a result of dry spell mitigation, but only in combination with N fertilizer. To upgrade on-farm water management in semi-arid SSA, the results suggest that supplemental irrigation combined with fertilizer may reduce the currently existing yield gap in small-holder farming systems.

Keywords: Dry spell mitigation; Supplemental irrigation; Maize yield; Water harvesting; Semi-arid; Kenya; Water use efficiency

1. Introduction

Small-holder farmers in semi-arid sub-Sahara Africa (SSA) often experience food shortages due to failing crop yields. Following the UNEP (1992) definitions, these climate zones in SSA usually have an annual average rainfall of 300–900 mm and 1.5–4 times higher potential evapotranspiration (ET_p) demand. Maize (*Zea mays* L.) is the staple grain for much of the SSA region. There is a consistent yield gap between small-holder farmers' long-term average maize grain yield, oscillating around 1 tonne ha^{-1} $year^{-1}$, as compared to on-station or commercial farmers' grain yields two to four times higher in these regions (Hassan et al., 1998). However, seasonal rainfall may not be too low for maize production per se. Rainfall distribution during the cropping season appears to be an important factor. Natural occurrence of dry spells due to high variation in rainfall distribution and amounts during season limits the crop development and result in yield reductions. In eastern Africa, Barron et al. (2003) estimated that a maize crop experienced dry spells longer than 10 days during critical flowering stage in more than 80% of seasons on sandy soil, and at least 60% of seasons on clay soil. This crop water deficit is worsened by the loss of substantial amounts of rain water as surface run-off (Ulsaker and Kilewe, 1984; Okwach and Simiyu, 1999). In addition, small-holder farmers often use low or no fertilizer for 'low-value' crops such as maize. To meet future increased food demand in SSA, current farming systems need to be more efficient in both farm water and nutrient management.

Several improvements to current small-holder farming practices have been suggested to increase rainfall infiltration and reduce surface run-off. In situ water harvesting, such as use of micro-catchments, are commonly practised alongside terracing to increase infiltration and reduce surface run-off. Improved soil organic matter content, and reduced tillage can further increase soil water storage capacity to help bridge intra-seasonal dry spells. Although such in situ water harvesting has a positive effect on soil water availability, they may prove insufficient to bridge intra-seasonal dry spells of 10–15 consecutive days, which frequently occur due to poor rainfall distribution.

Another proposed strategy is response farming. This is based on the use of an area's long-term rainfall characteristics in developing crop management guidelines. The aim is to reduce risk of crop failure due to water stress by tailoring crop management to seasonal outlook (Stewart and Faught, 1984; Keating et al., 1991; Wafula, 1995).

A further improvement of small-holder farming practice in SSA is to use supplemental irrigation (SI) for staple crops such as maize. The rationale is to supplement rain water and