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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Determining water use of indigenous grain and legume food crops

The Water Research Commission (WRC) commissioned a research project to quantify and predict water use of selected indigenous legume and grain crops for sustainable rainfed food production in South Africa.

Background

Interest and research on indigenous food crops has been steadily increasing in South Africa and elsewhere. This has been driven by realisations of increasing water scarcity, growing populations and increasing food and nutrition insecurity among the rural poor.

This commissioned project sought to review available literature to select and motivate indigenous legume and grain food crops for the study; measure the range of water use of selected crops as sole crops and intercropping under known environment conditions; model water use and agronomic management of selected crops as sole crops and intercropping for extrapolation to fit a range of agro-ecological zones suitable for rainfed farming; and formulate recommendations for best management practices on water use of indigenous grain and legume food crops.

Methodology

The methodology adopted for the study involved conducting several quantitative and systematic reviews focused on indigenous cereals and grain legumes. These reviews formed the basis for much of the crop selection.

Separate to the reviews, conventional field trials and modelling experiments were used to address objectives related to measurement of crop water use, crop modelling and development of best management practices.

Field trials were designed to quantify water use in sole crops as well as intercrops involving indigenous cereal and grain legumes. While the focus of the study was on indigenous cereal and legume food crops, major cereals and legumes were also considered, albeit to a limited extent and for benchmarking purposes only.

Overall, the range of crops that were studied during the project included maize landraces (***Zea mays*** L.), sorghum (***Sorghum bicolor*** L.), bambara groundnut (***Vigna subterranea*** L.). cowpea (***Vigna unguiculata***), dry bean (***Phaseolus vulgaris*** L.) and groundnuts (***Arachis hypogea*** L.).

Bambara groundnut

Results and discussion

The review of cereals showed that there was a wide range of African indigenous cereal crops that were nutritious and suited to rainfed conditions. Of these, the review noted that sorghum had a comparative advantage under rainfed conditions, due to its relatively high water use efficiency (WUE), drought, heat and aeration stress tolerance, high germplasm variability, comparative nutritional value, and existing food value chains.

At the time of the research project sorghum production was found to be low as maize tended to occupy ecological niches that were suited to its production. This had a carry-on effect on the entire value chain.

With respect to legumes, the review highlighted that grain legumes were rich sources of protein and micronutrients with dual purpose (human and animal consumption) thus making them ideal for crop-livestock systems that are typical of the semi- and arid tropics. While legumes showed large diversity and adaptability to the widest range of environment, current research and development had only focused on a few major legumes to the detriment of minor grain legumes, which are indigenous to Africa and more adaptable to water-limited conditions.

Results of field trials for sole crops confirmed the major findings of the literature reviews. Under rainfed field conditions, sorghum showed adaptation to low water availability mainly through physiological and phenological plasticity. Sorghum landraces performed statistically similar to hybrid and open-pollinated varieties confirming the potential of indigenous landraces that are currently used by farmers.

With respect to grain legumes, a comparative study of selected major and minor (indigenous) grain legumes species showed that while indigenous grain legumes performed well and showed adaptation to low water availability, they were generally out-performed by major grain legumes.

This was mainly attributed to the fact that major grain legumes have been the subject of much crop improvement, while minor grain legumes have not. Despite this, bambara groundnut emerged as an African indigenous legume with potential for further crop improvement.

The study assessed two intercropping scenarios, a sorghum-cowpea-bottle gourd and a maize landrace-bambara groundnut-dry bean intercrop. The focus was on cereal-legume intercrops that featured indigenous cereal and grain legumes.

Intercropping sorghum with cowpea and bottle gourd or maize landraces with either dry bean or bambara groundnuts did not have a negative effect on growth and yield of both sorghum and maize landraces.

Under limited water availability, intercropping resulted in more of a facilitative than competitive interaction. Under rainfed conditions, intercropping improved overall productivity of sorghum and maize landraces translating to improvements in water use, land use efficiency and WUE.

Overall, intercropping resulted in improved soil water availability as the legumes acted as a live mulch, hence minimising unproductive losses to soil evaporation. Thus, under rainfed conditions, intercropping cereals and legumes would be beneficial in terms of improving resource use efficiencies. Intercropping also offers long-term benefits in terms of sustainability through the legumes' ability to fix nitrogen.

However, the benefits of nitrogen fixed by the legumes to the current or subsequent cereal crop require further investigation.

A major aspect of the current study was to model the selected indigenous cereal and legume food crops for extrapolation to other rainfed ecologies in South Africa. Two models were selected for this purpose – Aquarop and APSIM. The two crop models are uniquely differnet, with AquaCrop being a simple water-driven model while APSIM is a complex radiation-driven model.

AquaCrop was therefore used to model sole crops while APSIM was applied for the intercrop for which it was most suited. For the sole crop, AquaCrop modelling focused primarily on sorghum since millets and bambara groundnut, harvest index and yield relatively well for all sorghum genotypes and different environments.

With respect to intercropping, the APSIM model was able to simulate the sorghum-cowpea intercrop system under different water regimes. The model gave reliable simulations of phenology, biomass, yield and crop water use for both sorghum and cowpea under the different water regimes.

Following calibration and validation of the crop models a secondary objective was to then apply the models for scenario analyses in order to develop best management practices. AquaCrop was applied for a range of agro-ecologies across KwaZulu-Natal to assist with generating best practice management recommendations for cultivar choice and planting date selection.

Similarly, APSIM was also used to assess different management scenarios for selected areas in KwaZulu-Natal and to develop best management practices for improving water use efficiency under intercropping.

Conclusion and recommendations

Major recommendations that were developed included cultivar selection, selection of suitable planting dates, use of rainwater harvesting to increase water availability, use of mulches to minimise soil evaporation and increasing plant populations in favourable agro-ecologies.

In terms of agricultural water management, deficit irrigation was recommended for areas that had access to water for supplementary irrigation. However, proper irrigation scheduling is a prerequisite to achieving improvements in yield and WUE.

In conclusion, the current project succeeded in quantifying water use of indigenous cereal and legume food crops under varying environments. While the extrapolation to other rainfed agro-ecologies was limited to KwaZulu-Natal, due to the availability of reliable data, the framework developed can be applied for a range of environments given that soil and climate data are available.

The study provides a strong case for the promotion of underutilised, indigenous and traditional cereal and legume grain crops, especially in semi-arid environments. Underutilised indigenous cereal and legume food crops have a potential role to contribute to crop production under climate variability and change as well as to promoting food and nutrition security in semi-arid regions.

However, a major limitation to their production relates to the low potential and attainable yields of these crops, in particular, minor grain legumes. This requires targeted efforts at crop improvement to improve their yields.

In the short to medium term, the use of best management practices that include intercropping, appropriate cultivar and planting date selection as well as rainwater harvesting and conservation techniques have potential to improve current yields and improve WUE under rainfed conditions.

The use of crop models, and the ongoing work to model underutilised indigenous crops, should be commended and furthered. This is because crop models are useful in assisting in determining the yield and water productivity as well as suitability of production of underutilised indigenous crops under different management and biophysical scenarios.

Related project:

To order the report, *Determining water use of indigenous grain and legume food crops* (**WRC Project No. TT 710/17**), contact Publications at Tel: (012) 761 9300; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.