EXECUTIVE SUMMARY

THE INFLUENCE OF DIFFERENT WATER AND NITROGEN LEVELS ON CROP GROWTH, WATER USE AND YIELD, AND THE VALIDATION OF CROP MODELS

Water is in high demand in South Africa, so it is imperative that the use of irrigation water be optimized. This multi-disciplinary project arose out of a need to gain a better understanding of crop growth and water use. With the improvement of crop simulation models in mind, field experiments were designed to answer specific questions where information was lacking. The aims of the study centred around characterizing the interactive effects of water and nitrogen on the growth, water use and yield of irrigated spring wheat. A comprehensive series of field measurements was made over four seasons, and the information was then used to validate various crop models.

The detailed objectives for this project had three main focus areas:

(i) To characterize the development of the crop canopy and the resistances to water flow in the soil-plant-atmosphere continuum under different water-nitrogen regimes (in a field experiment).

(ii) To validate, under South African conditions, selected crop models used in irrigation planning and management, and to make recommendations for improvements.

(iii) To test the reliability of the BEWAB irrigation scheduling program under the different water-nitrogen regimes, particularly in connection with the water use, water use efficiency and yield predictions.

The characterization of crop canopy development was undertaken in great detail in all four wheat seasons by means of growth (e.g. leaf area and biomass) and physiological (e.g. photosynthesis) measurements. A detailed study of the often neglected crop root system was also made, with the help of a minirhizotron video camera system. Plant water relations were monitored by means of leaf water potential measurements, and the rate of sap flow through a single stem was successfully measured after adapting and calibrating the heat pulse method.

The CERES, PUTU and SHOOTGRO wheat crop growth models, selected as typical of those in current use, were calibrated and validated under South African conditions using the comprehensive dataset generated in the field experiments. The ability of the models to accurately simulate various aspects of wheat production was tested under different levels of applied water and nitrogen. Certain inadequacies were highlighted which could enable model developers to make the necessary refinements.

The BEWAB irrigation program was used to schedule the irrigation throughout the four-year project, and although it was developed in a cooler region it proved to be quite reliable in a warm irrigation area such as Roodeplaat, when tested against measured yield and water use data. However, certain modifications could now be made by the developers of BEWAB, based on the information gained in this project, which would broaden its application base.

One of the major achievements in this project was that several specialized scientific techniques were adapted and brought to an operational level for wheat crop measurements:

Firstly, the heat pulse system, which had previously been used only on plants with robust stems such as soybeans, was adapted for use with thin-stemmed wheat tillers. The technique was then calibrated and used to make continuous measurements of single stem transpiration under field conditions. The success of this development will allow the heat pulse system to be used to study the transpiration of a wide range of plants, including grasses.

Secondly, a video camera was used to non-destructively monitor root growth and development by means of minirhizotron tubes installed in the soil under the wheat crop. This technique is new in South Africa and was evaluated in comparison with the destructive coring method. It allows a much more detailed study to be made of the root system than was previously possible, and is particularly suited to monitoring root turnover over long periods.

Thirdly, a detailed field evaluation was undertaken of a system for measuring single leaf photosynthesis. Guidelines were developed for the precautions necessary when using a leaf chamber in order to obtain accurate measurements on a routine basis. The technique was then used to establish the relationship between photosynthesis, leaf age and leaf nitrogen content for wheat leaves throughout the growing season.

Another valuable contribution arising from this study was the guidelines developed for farmers regarding the amount of irrigation water to apply and the optimal nitrogen application recommended for a specific target wheat yield in the warm irrigation region. For example, for spring wheat cultivars grown in a deep soil with a high clay content, in order to obtain a grain yield of 6-7 t ha^{-1} then a nitrogen fertilizer application rate of 135 kg N ha^{-1} is recommended. The Roodeplaat study indicated that a seasonal water use of approximately 550 mm would be required for this target yield if irrigation was applied weekly, but only 440 mm if it was applied once every two weeks. The efficiency of irrigation water could thus be improved if these guidelines are followed, and a higher yield produced per unit of irrigation water applied.

The main legacy of the project will be the large and comprehensive dataset that was generated, which characterizes the effects of different water and nitrogen application levels on the growth, water use and yield of a spring wheat crop. This information will be of great value both from a scientific standpoint, in that the processes involved are now better understood, and in the calibration, validation and refinement of crop growth models. The dataset is now available to any scientist who is able to make further use of it. In this way it is felt that the study has contributed to the furtherance of agricultural science in South Africa at the present time, and that the effect of the scientific progress will be realised in the years to come.