Advanced Fertigation Systems (AFS) provides a management system for irrigation enterprises that result in optimum plant water use, nutrient uptake and production levels in centre pivot and sprinkler irrigation systems. The research and development activities undertaken to refine these systems indicate that it is possible to achieve productivity gains of between 20-40% without any increase in irrigation rates or nutrient applications on a variety soil types and water sources that include artesian, waste water and water abstracted from below water table mining operations.

In some instances it has been possible to grow productive and healthy crops with significantly less added nutrients than is possible under conventional practices and also sustain production on soils with stable but low phosphorus levels, resulting in reduced risks of nutrient loss by removing the requirement for capital applications.

Management System

The AFS management system increases water use efficiency and reduces the risk of nutrient loss through the application of processes that integrate accepted scientific principles in the fields of plant physiology and chemistry. AFS is an adaptation of the open hydroponics technology used in drip irrigation and is comprised of, but not limited to, the following principles;

• Nernst Equation (for maximising plant nutrient absorption);
• Penman-Monteith Equation (for irrigation scheduling);
• Liebig’s Law (for balanced nutritional solutions);
• Truog’s Diagram (effect of pH on availability of nutrients) and;
• Mulder’s Chart (interactions between plant nutrients).

The AFS management system integrates an irrigation forecasting model with a prescribed fertigation formulation, taking into consideration specific conditions such as climate, irrigation water quality, soil characteristics and plant nutrition requirements.

AFS also takes into account the International Plant Nutrition Institute’s “4R” fertiliser management principles which acknowledges large efficiency gains can be made through its adoption.

The elements of the “4R” principles apply to AFS in the following manner;

• Right amount: Proportions of nutrients are calculated according to specific plant requirements taking into consideration the background nutrients of the irrigation water source.

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- Right place: Correct irrigation scheduling results in the nutrients being delivered, in solution, to the root zone, making them readily available for plant uptake.

- Right time: The nutrient solution is injected into the irrigation water at a rate proportional to daily plant requirements.

- Right source: Only technical grade fertilisers are used so that the exact nutrient composition can be calculated.

The fertigation formulation can also be adjusted to account for product quality allowing specific market windows to be targeted for characteristics such as protein levels and digestibility of fodder crops.

Nutrient Management

The application of the AFS management system results in water and nutrients being provided to the plants in dilute amounts on a daily basis, as opposed to using the soil as a storage medium that releases nutrients to the plants over a greater period of time, which can result in limitations associated with nutrient availability and a greater risk of environmental loss.

This system applies the physiological principles of plant nutrition to fertiliser application through the irrigation system. The fertigation formulation is maintained at a constant pH to optimize the availability of elements for maximum plant uptake. This system also follows the rules of fertigation whereby nutrient applications are matched to the daily growth requirements of the plants, therefore alleviating build-up of nutrients in the soil. This reduces the risk of nutrient losses through leaching and runoff and avoids excessive build-up of salts in the soil.

The concentrated fertigation formulation is introduced into the irrigation water by pumps that are attached to flow meters to ensure calculated proportions are injected. The composition of the nutrient solution is based on the elemental composition of the irrigation water and the fact that plant nutrient uptake can be maximised if the ratio of ions in the solution matches the plant requirements. The background concentration of nutrients in the water source is therefore supplemented with nutrients to make it suitable for plant growth.

The fertigation formulation is an electrochemically balanced formulation comprising of the essential elements required by the plants. It is injected into the irrigation system in the quantities required, as determined through water, soil and plant tissue analyses.

The total amount of nutrients applied from all sources is calculated according to the following factors:

- Irrigation rate,
- Water analysis,
- Soil analysis,
- Plant requirements,
- Production levels,
- Nutritional exports,
- Nutrient recycling.

This is achieved through the application of published nutritional and production standards specific to the crop being produced.

Irrigation Scheduling

Irrigation schedules are formulated up to six days in advance using a modelling program that integrates the Penman-Monteith equation with local conditions and stress factors that affect crop growth.

The data used to generate the irrigation schedule is collected by a site weather station and soil moisture probes. This data is viewed remotely and downloaded into the irrigation scheduling program on a daily basis.

This results in the calculation of "ETa" which represents adjusted evapotranspiration. The difference between ETa and standard evapotranspiration (ETO) has been found to be as much as 10% which is quite significant in terms of irrigation volumes and pumping costs. The difference between standard ETO and Eta is demonstrated below in Figure 1.

The irrigation schedule is reviewed on a daily basis according to data generated from soil moisture probes and weather observations. It is therefore calculated according to plant water requirements and the soil moisture content for each irrigation zone.

The irrigation schedule is also calculated so that evaporation and soil infiltration rates are not exceeded therefore ensuring that run-off or leaching does not occur as a result of irrigation. This is achieved by measuring the soil characteristics such as infiltration rate and bulk density and incorporating the data into the AFS irrigation model.

If the soil profile reaches field capacity following rainfall or due to over application, irrigation of the particular area is ceased in order to prevent the possibility of nutrient loss occurring. Irrigation is not resumed until the soil moisture levels return to an acceptable level in consideration of the required irrigation application rate, hydraulic conductivity of the soil and the prevailing evapotranspiration rate.

Monitoring Program

A monitoring program forms a fundamental component of the AFS management system. This provides important information on plant performance and soil responses to application rates allowing adjustments to be made based on the principles of adaptive management.

Effectively, crop performance, soil moisture and nutrient levels provide valuable feedback that is constantly used to guide management decisions. This program also allows a nutrient audit to be carried out which accounts for the level of nutrient uptake and therefore environmental performance of the system.
Crop Production

Crop production is measured on a weekly basis. This involves comparing dry matter production between different irrigation rates and against benchmark water use efficiency values (kg/ha/mm.Eta) for the particular crop with the results used to fine tune the irrigation schedule. Figure 2 demonstrates the difference in plant production as a result of different irrigation and fertigation rates and compares them with accepted water use efficiency benchmark.

This model also allows a crop harvesting schedule to be developed in order to optimise yield and quality considerations.

Leaf Tissue Analysis

Leaf tissue analysis is used to monitor actual plant uptake of the applied nutrients. The results of this component of the monitoring program are compared with accepted scientific standards for the particular crop and adjustments made to the fertigation formulation or injection rate to account for any deficiencies or toxicities that may be occurring. Figure 3 demonstrates the results of leaf tissue analysis generated through the AFS agronomy program.

Soil Sampling

Sampling of the soil and soil solution is carried out using standard agricultural sampling methods and analysis. This information is used to assess the level of nutrient loss risk and when combined with the leaf tissue analysis, used to determine the efficiency and effectiveness of the management system, allowing appropriate adjustments to be made if required.

Soil Moisture

Soil moisture and electric conductivity is measured on a daily basis to assess the efficiency of the application system. Soil moisture probes measure the soil moisture content at six different depths to a maximum depth of 900 mm. The probes are monitored and adjustments made to the irrigation schedule in response to the data that is received (presented in Figure 4). This ensures that nutrients and water are being applied according to the specifications of management system therefore avoiding over application or loss of nutrients past the root zone.

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Nutrient Audit

Analysis of the end product is carried out to measure the amount of nutrients removed from the system. This is then compared to the amount of nutrients added in the water and fertilizer applications to formulate the nutrient audit, which calculates the balance of the nutrients remaining in (or removed from) the system. This information is combined with trends of nutrient levels in the soil test results, providing a high level of environmental accountability.

AFS Irrigation Manager

All of the data collected through the monitoring program is downloaded into the AFS Irrigation Manager. This web-based system is an integrated user interface (Figure 5) that can be viewed in real time and used to process the data collected into relevant reports, allowing necessary management decisions to be made.

Conclusions

Appropriate irrigation scheduling and nutrient applications through the use of the AFS management system will ensure that nutrient loss pathways are minimised and that irrigation applications are maintained at optimum levels thereby maximising the genetic potential of the plant under the specific climatic conditions, and increasing productivity through optimised water use efficiency and nutrient uptake.