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Water use optimisation based on the concept of Partial Rootzone Drying

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Abstract Partial Rootzone Drying (PRD) is the creation of simultaneous wet and dry (or drying) areas within the root zone. Only part of the root zone is irrigated and kept moist at any one time. This new irrigation strategy allows the exploitation of drought-induced abscisic acid (ABA) based root to stomata signaling system to water saving. In this research, the PRD technique is examined and simulated for wheat and maize crops in the Mashtul Pilot Area (MPA), Egypt using Saltmed model. The technique causes the stimulation of physiological responses which are normally associated with water stress and this result in a significant reduction in water use through the production of chemical signals in drying roots. The results confirmed an increase in irrigation water productivity using PRD comparing with conventional flood irrigation. The research highly recommends applying the PRD method in new reclaimed areas in Egypt to save water and improve crop quality.

1. Introduction

Irrigation requirements are sometimes estimated from environmental data (pan evaporation, soil moisture reserves and rainfall) and crop factors. Crop factors are multipliers which reflect the water requirement of a particular crop at different times of the year and depend on variables such as canopy area and stage of growth. They can vary by a factor of five and the success of this method of determining irrigation input is very much dependent on the use of realistic crop factors. In determining these factors, little thought is given to internal physiological changes in the plants which may substantially influence their efficiency of water use in the short term. For example, it has been known for a long time that water deficits will induce changes in the gas exchange characteristics of a plant which result in reduced water loss. Such a decrease in water use would obviously be an advantage if it could be achieved without detriment to the crop or any other aspect of crop performance [1]. However, to get the plant to exhibit these changed characteristics, it would normally be necessary to induce a degree of water deficit. This may be difficult to achieve in a conditions way and furthermore, the plant will recover over a period of time, making repeat water deficit events necessary for a sustained effect. This may be possible, but difficult to achieve in practice, and it is known that sustained water deficits usually result in a reduction in fruit yield. Ideally, it would be desirable to separate the positive effects of water deficits (improved water productivity and reduced allocation

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of resources to vegetative growth in comparison to fruit growth) from the negative effects such as reduced crop yield.

PRD, as the name suggests, is the creation of simultaneous wet and dry (or drying) areas within the root zone (Fig. 1). Only part of the root zone is irrigated and kept moist at any one time. PRD is implemented by irrigating one side of the plant row and allowing the other side to dry out. The irrigations are then alternated to the dry side after a set period of time and then back and forth thereafter the same period of time. If only part of the root system is dried and the remaining roots are kept well watered, chemical signals produced in the drying roots will reduce stomatal aperture. At the same time the fully hydrated roots maintain a favorable water status throughout the aerial parts of the plant. In other words, it is possible to separate the biochemical responses to water stress from the physical effects of reduced water availability. In addition to reduced stomatal conductance, it is noted that shoot extension is also inhibited. A surprising finding is that the effect is temporary, and despite the fact that part of the root system remained dry, stomatal conductance, photosynthesis and growth returned to pre-treatment levels within a few weeks [2,3].

Armed with knowledge about the transient nature of the effect and the likely role of abscisic acid (ABA) [4], it is possible to devise irrigation schedules to maximise the production of ABA and hence its inhibitory effects on transpiration and growth. In practice, this means applying water to one side of the plant for about two weeks and then changing to the other side. During the two week irrigation cycle it is important that water is supplied with sufficient frequency to the wet side to prevent excessive soil drying and to meet the needs of the whole plant. If all of the plant's roots become dry, a water deficit will be induced and this may impact negatively on crop yield. For example, in grapevines subjected to PRD, there is a consistent reduction in vegetative growth as measured by pruning weight. Another measure of canopy density is the amount of light reaching the bunch zone and this figure is consistently higher in PRD than in control vines. It has been a consistent feature of all trials that there was no significant reduction in yield due to PRD treatment even though irrigation amount is halved. As a result, water productivity is effectively doubled in response to PRD. The aim of this research is to examine and simulate novel irrigation method (Partial Rootzone Drying, PRD), which would stimulate the endogenous stress response mechanisms of wheat and maize crops in the Mashtul Pilot Area (MPA), Egypt using Saltmed model so that vigour is reduced and the efficiency of water use is enhanced [5]. This is to be achieved by the manipulation of the hydration status of parts of a crop's roots could be used to control vegetative vigour without detrimental effects on canopy water relations. In this paper, the PRD technique is researched for wheat as a winter crop and maize as a summer crop in Egypt. The technique causes the stimulation of physiological responses which are normally associated with water stress and this result in a significant reduction in water use through the production of chemical signals in drying roots. In addition, the research provides low cost irrigation techniques at farmers' level, monitor performance of the new techniques, and assessing the feasibility of implementation.

2. Implementation of PRD

There are several ways to implement PRD. In Australia where the technique was developed, vineyards have shallow soils and effective separation of the root system was achieved by drip irrigating the area between pairs of vines down the row while the areas between the vines in each pair were allowed to dry. When the rate of soil drying in the non-irrigated areas slowed or stopped, these areas were then irrigated on a normal schedule while the previously irrigated areas were allowed to dry. Switching the irrigated versus non-irrigated areas was done to maintain the beneficial levels of cytokinins and ABA. The first PDR irrigation systems installed consisted of two drip lines per row, each corresponding to an irrigation zone. Currently on the market are double, fused drip tapes that ease

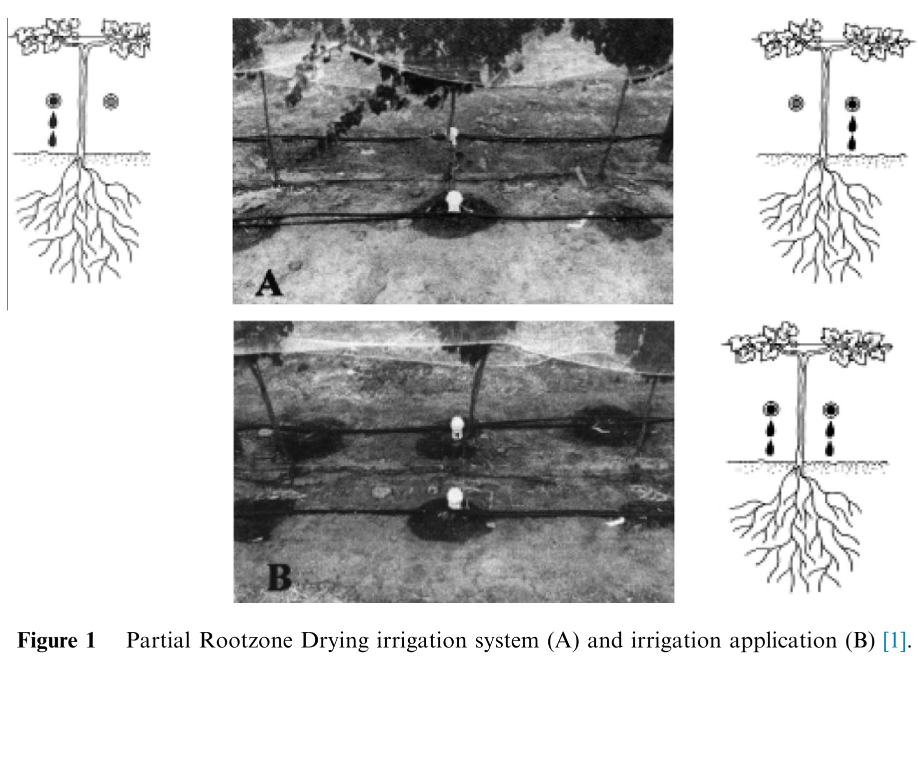

Figure 1 Partial Rootzone Drying irrigation system (A) and irrigation application (B) [1].