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学位論文の内容の要旨

Irrigation scheduling is the key factor for increasing irrigation efficiency and crop yield as well as the control of soil degradation under low quality water use. Strategies for irrigation scheduling include appropriate timing and intervals of irrigation according to soil water holding capacity, uniformity of irrigation system and, evapotranspiration. Drip irrigation system (DIS) is designed for high-frequency irrigations to maintain soil moisture at an optimal or near optimal level for maximum yield during the whole growing season. The effectiveness of DIS depends as well on the quality of the water under use and the maintenance of the system. Water quality can considerably affect DIS scheduling and efficiency due to emitter clogging by sewage or saline water and the level of soil solution concentration in the crop root zone. A study on DIS scheduling as affected by water quality and evapotranspiration was carried out at the Arid Land Research Center, Tottori University, and the Tohaku irrigation project area, Tottori, Japan (35°32′N and 134°13′) during 2002 and 2003. This study included the following three parts:

The first part of the study was on the estimation and forecast of ETo to improve irrigation scheduling and consequently water use efficiency. Six ETo estimation models were assessed statistically against experimentally determined values in a humid temperate environment. The ETo estimates were obtained using the Penman (PE), Penman-Monteith (PM),

Wright-Penman (WP), Blaney-Criddle (BC), Radiation balance (RB), and Hargreaves (HG) models. The ETo forecasts were obtained using 5-yr or 8-yr weather data and 1- and 2-year return period approach. Compared with the lysimeter values, it was observed that all the six models over or under-estimated the ETo. Nevertheless the PE model produced the best ETo estimates as assessed by root mean square, mean bias error, and t-test statistics for the temperate environment. In general, the ETo forecasts obtained using 8-yr weather data were better than 5-yr. The 2-yr return period ETo forecasts were better than 1-yr return period, regardless of the duration of weather data.

The second part was to investigate the impact of selected water quality (chemical and biological) in effluents on water discharge rate and distribution uniformity from emitters with different orifice sizes (OS), in-built filtration areas (FA), pressure compensation (PC) systems. The field experimental layout in the Tohaku irrigation project included 8 types of on-line and in-line emitters each on 50 m long laterals connected to the field irrigation line without filters. The results of Biological clogging agents (BCAs) count indicated that during 2002 it was highest at the beginning of irrigation in April, and decreased with time until September, while during 2003 it increased with time and peaked at the end of August. Emitter discharge rates increased with increasing OS, FA, and working pressure (WP) and decreased with increasing BCAs counts. Because BCAs were the only dynamic variables in the above relationship, we concluded that BCAs-induced clogging is a major reason for clogging when filters were not installed in field irrigation lines. Four selected emitters from the first year's experiment and another 2 new emitter types were used to assess the impact of chemical treatment on preventing or reducing emitter clogging induced by BCAs, and the performance of drip irrigation. Each of the 6 types of emitters was installed on two separate laterals, in two similar subunits of DIS, for two different management schemes of with and without chlorine injection into the irrigation water. The discharge from emitters increased with chlorine injection into the irrigation water and with increasing OS and FA, but decreased with increasing BCAs counts. The values of the mean discharge ratio variation (Dr) indicated that the cumulative impact of manufacturing variations (Vm) and that induced by BCAs and chlorine injection on emitter discharge was low during the irrigation season when chlorine was injected into the irrigation water. The values of the statistical uniformity coefficient (U) were more than 93 % for both managements, indicating that the uniformity of emitters discharge and consequently, clogging along a lateral were high.

In the third part of the experiments, the effects of (i) irrigation regimes, (ii) time after irrigation, and (iii) crop growth stages, on soil water content (θw) and soil solution salinity (ECw) was studied at different radial distance from the emitter (lateral pipe). The experiments were carried out in the sand dune field of the Arid Land Research Center,

Tottori University. Three irrigation regimes were applied. The first irrigation regime (Id) was based on daily crop water requirement. Two other irrigation regimes were based on Id and 20 % and 40 % leaching (Id・1.20 and Id・1.40). The simultaneous distribution of water and solute under drip irrigation was measured using Time Domain Reflectometry (TDR). The results indicated that θw and ECw increased in the order early stage (ES) < mid-stage (MS) < late stage (LS) for all irrigation regimes. The maximum θw and minimum ECw coincided at 10 cm radial distance from emitter (r10) during all crop growth stages for all the irrigation regimes. The same trend was noted for 20 cm radial distance from emitter (r20) under Id・1.40, but only during the ES for Id and during the ES and MS for Id・1.20. The ECw increased significantly in the order r10 < r20 < r30 (30 cm radial distance from emitter) during all the crop growth stages for all the irrigation regimes. Time elapsed after irrigation was terminated until θw attained its maximum level in the crop root zone changed with crop growth stages. It is therefore suggested that irrigation should commence at different times before noon, depending on the crop growth stage, so that maximum θw (minimum ECw) will coincide with maximum evapotranspiration (ETo). Interaction between θw and ECw for a given radius and the different crop growth stages showed that the influence of θw on ECw was restricted to a small radius of about 0-20 cm from the emitter. Beyond this range, increases in θw did not significantly affect ECw. The first irrigation regime (Id) was found unsuitable for an irrigation regime involving use of saline water. A distance of about 25 and 30 cm was suggested for 2 consecutive emitters on a lateral pipe under Id・1.20 and Id・1.40 respectively, to minimize ECw along the lateral pipe. Moreover, a combined irrigation scheduling of Id・1.40 for ES and MS, and Id・1.20 for LS was suggested to increase the irrigation efficiency.

論文審査の結果の要旨

点滴灌漑は水の効率的利用に優れ土壌中の塩類集積が少ない灌漑法であるので，乾燥地域において広く利用されている。点滴灌漑の用水計画では，圃場における土壌水分特性，畑地水分消費特性及び気象特性等の基礎的要因を明らかにして，作物の蒸発散量や根群域水分量を検討し，灌漑の間断日数と計画灌漑水量が決定される。

本研究では，より正確な蒸発散量の算定手法を導入すると同時に，灌漑水の水質要因に着目して塩水と富栄養化した灌漑水を取り上げ，点滴灌漑の用水計画に必要な基礎的要因の検討を試みたものである。本研究の成果は次の 3 つの部分から構成される。

1．イラン国と本学の乾燥地研究センターの圃場を取り上げ，気象データを利用した 6 種類の蒸

発散量算定モデルを用いて牧草の蒸発散量について検討した。同時に短期間(8 年以内)の気象データを用いる場合の蒸発散量の予測値に関し統計的な検討を行った。モデルの種類は, Penman モデル(PE), Penman-Monteith モデル(PM), Wright-Penman モデル(WP), Blaney-Criddle モデル(BC), Radiation balance モデル(RB), Hargreaves モデル(HG)である。ライシメーターで得られた実験値を用いて検証した結果, BC＞WP＞PM＞HG＞RB＞PE の順序で誤差が少なく, PE モデルによる場合が統計的にも信頼性の高い予測値を示すことを明らかにした。

2．国営東伯農業水利事業地区内に, 現在よく利用されている 4～8 種類の点滴エミッターを供試して, 点滴灌漑施設の生物学的目詰まり障害に関して検討を行った。灌漑水中のプランクトン数は, 2002 年の場合灌漑開始時期の 4 月, 2003 年の場合 8 月末にピークが現れ, 灌漑水の富栄養化は年々増加した。プランクトン数の増加に伴って, 滴下口径の小さいエミッターほど滴下流量が減少し, 目詰まり障害が増加した。塩素処理水を注入して目詰まり防止を検討した結果, エミッターの滴下流量が改善され, 目詰まり障害防止に有用であることが提案された。

3．乾燥地研究センターの大型ガラス室砂床にトウモロコシを栽培して塩水灌漑を行い, エミッターからの湿潤半径内における土壌水分量(θw), 土壌水の電気伝導度（ECw）に関し, 3 種類の灌漑水量, 灌漑後の経過時間, 作物生育時期等との関係について検討を行った。θw と ECw は, 灌漑水量にかかわらず, 生育の初期, 最盛期, 後期の順に増加し, θw の最大値(ECw の最小値)は, 各灌漑水量及び生育時期においてエミッターから半径 10cm 離れた位置に発生した。この位置の ECw の最小値は, 標準灌漑水量の場合灌水後 2～3 時間に生じ, 灌漑水量が大きい場合さらに 1 時間程度遅れた。塩水灌漑において ECw を小さくして適用効率を高くするには, エミッター間隔は 25cm～30cm, 灌漑水量は標準区より 20～40%増加させることが提案された。

本研究では, 乾燥地の点滴灌漑の用水計画において, 作物の蒸発散量予測について正確な算定手法を提案すると同時に, 灌漑水の水質を考慮した用水計画の検討を行い, 新しい基礎的要因をいくつか明らかにしている。これらは, 乾燥地における点滴灌漑の用水計画において, 現在課題とされる灌漑システムの目詰まり障害防止や節水的な灌漑水量の決定に大きな意義を有するものであり,学位論文として十分な価値があるものと判定する。