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SUMMARY OF DOCTORAL THESIS

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Title: Study on Evaluation of mulching effect and establishment of irrigation threshold for water-saving production
（節水のためのマルチング効果と灌漑時期の評価に関する研究）

Given the current demographic trends and global warming, as much as 60% of the global population may suffer serious water scarcity by the year 2025. Agriculture is likely to suffer the most unless more efficient water management is practiced, particularly in drylands. Mulching is an efficient method controlling evaporation. Reducing evaporation loss helps to conserve soil moisture and control salt accumulation. Since saline water resources are more abundant than fresh water, the careful use of saline or diluted seawater is important for agriculture. Irrigation scheduling also plays an important role in developing water-saving agriculture. Determination of threshold value at which irrigation should be scheduled is necessary for water-use-efficient production. This study was carried out from 2005 to 2008 at the Arid Land Research Center, to evaluate mulching effect for sustainable agriculture and establish irrigation threshold for water-saving production.

In the first part, ameliorative effect of mulching on water use efficiency (WUE) of Swiss chard and salt accumulation under saline irrigation was investigated in order to conserve soil water and maintain lower level of salts in the topsoil. A pot experiment was conducted in a greenhouse to evaluate the effects of three mulching types together with diluted seawater irrigation. Seawater was diluted to achieve the electrical conductivity of irrigated water as 4.8 and 7.4 dS m^{-1}. Pots were mulched in the form of gravel, pine-needles and rice-straw, respectively. Mulches significantly reduced evapotranspiration (ET) in all the treatments and reduced salt accumulation under high saline irrigation. High diluted seawater irrigation could be used under mulch condition without serious salinity-damage to Swiss chard. Averaged soil temperature among mulches differed as gravel > rice-straw > pine-needles > no-mulch during winter season, regardless of soil depth. Mulching improved plant biomass as well as WUE. Under high saline water, mulches were differed for the dry matter production and WUE in the order of gravel > pine-needles > rice-straw > no-mulch. The experiment indicated that mulching practice can be also used favorably for crop production under saline irrigation.

In the second part, the effect of gravel mulch (GM) and rice-straw mulch (RM) on the soil salinity, ET, fresh and dry weight yield and WUE of Swiss chard were investigated. Three weighing lysimeters were irrigated with diluted seawater (6.86 dS m^{-1}) from below to allow the water table to keep between 50 cm and 80 cm depth. At the end of the experiment, the electrical conductivity of 1:5 soil extract was measured in four soil depths (5, 10, 15, 25cm). The cumulative ET was higher with no-mulch (292 mm) than under RM (254.7 mm) and GM (216.6 mm). The fresh and dry yields of Swiss chard were, respectively, 76% and 113% higher under RM and 49% and 64% higher under GM than under no-mulch. The electrical conductivity of 1:5 soil extract in the top 25 cm soil layer was lower under mulching than under no-mulch. Mulching increased the soil temperature slightly. These contributed to the increase of yield under mulching as compared to under no-mulch treatments. RM treatment increased WUE by 143% and 10% as compared to no-mulch and GM treatment, respectively. Thus mulching using RM is recommended for reducing salinity effect under shallow water table of saline water and improving WUE.

In the third part, effects of mulching and sub-surface seepage irrigation on soil water, soil temperature, growth, berry quality and yield of grapevines (*Vitis vinifera* L.) were investigated. This experiment was conducted in a greenhouse using 4 weighing lysimeters from 5 June to 21 Sep., 2008. Four treatments: mulching combined with sub-surface seeper hose seepage irrigation (MSS);

no-mulch combined with sub-surface seeper hose seepage irrigation (SS); mulching combined with surface seeper hose seepage irrigation (MS); no-mulch combined with surface seeper hose seepage irrigation (S), were used. Growing investigation was included of shoot length, leaf area, photosynthesis, berry diameter, berry sugar content, fresh yield and dry yield of grapevines. MS gave the highest fresh yield while SS gave the lowest value. Under both mulching and no-mulch conditions, the sub-surface irrigation reduced the fresh yield compared with surface irrigation. The higher yield, faster shoot length growth and larger berry diameter for MS could be related to the higher water content at top soil. These combination of mulch and seepage irrigation were differed for the water use efficiency (WUE) in the order of MS > MSS > SS > S. Compared with SS, the berry diameter, fresh yield, WUE, and berry sugar content for MS were enhanced by 2.8 mm, 271.5 g/tree, 33% and 15%, respectively. MSS gave higher berry sugar content than MS, which could be attributed to the lower soil water at the top soil layer under the condition of sub-surface irrigation.

In the fourth part, determination of soil water potential threshold for scheduling irrigation using change in berry diameter during the berry-growth stage of grapevine. After irrigation, grapevine was allowed to experience decreasing soil water potential. The instantaneous variations in the berry diameter were measured by photogrammetry simultaneously using two cameras. The phenomenon that berry diameter increased at night and decreased in the day was observed. Berry diameter increased gradually and soil water potential decreased after irrigation. For 33 hours after stop the irrigation, the trend value of berry diameter was increased to 23.7mm and soil water potential at the depth of 10cm decreased to -5.4kPa, but after that berry diameter decreased due to water stress of grapevine. Relationship between berry diameter and soil water potential can show the sensitivity of water stress of grapevine. In contrast, photosynthesis and transpiration remained unaffected by decreasing soil water potential until it became -9.3kPa beyond which photosynthesis decreased significantly. Thus, berry diameter was a better indicator of sensing water stress than photosynthesis and transpiration. And the soil water potential value of -5.4kPa should be considered as the soil water potential threshold for irrigation scheduling during the berry-growth stage in grapevines.

In the fifth part, the critical value of soil water potential was discussed for irrigation scheduling during berry ripening stage of grapevines. When soil water potential decreased from -13.2kPa to -14.7kPa, photosynthesis, stomatal conductance, transpiration, extrinsic WUE (= photosynthesis / transpiration) and intrinsic WUE (= photosynthesis / stomatal conductance) decreased rapidly and did not recovery thereafter. In contrast, the berry size remained almost unaffected by decreasing soil water potential until it became -16.2kPa beyond which the berry shrunk significantly. Thus, photosynthesis response was more sensitive to water stress than berry size during the berry ripening stage. When stomatal conductance < 0.03 mol H_2O m^{-2} s^{-1} (corresponding to -14.7kPa), photosynthesis, intrinsic WUE and extrinsic WUE decreased rapidly, whereas substomatal CO_2 concentration increased steeply, indicating that non-stomatal limitations to photosynthesis become dormant. A more sensitive response of photosynthesis to water limitation compared to stomatal conductance at this last stage of soil drying led to a decrease in photosynthesis/stomatal conductance. When stomatal conductance > 0.03 mol H_2O m^{-2} s^{-1}, photosynthesis and substomatal CO_2 concentration decreased, whereas extrinsic WUE and intrinsic WUE usually increased. Therefore, stomatal limitations seem dormant at this stage. In areas where water availability is low or moderate, the critical soil water potential range for irrigation scheduling should be between -13.2 and -14.7kPa (corresponding to stomatal conductance range of 0.09 - 0.03 mol H_2O m^{-2} s^{-1}). After irrigation, soil water potential should be kept lower than -6.9kPa because the highest intrinsic WUE occurred in the soil water potential range from -6.9 to -14.6 kPa. In hyper arid and arid areas, the soil water potential threshold for irrigation scheduling should be considered as -16.2kPa (corresponding to stomatal conductance value of 0.02 mol H_2O m^{-2} s^{-1}) in this important stage of economic yield development and fruit quality in grapevines to get cost-effective use of water resources.