1. Summaries of Doctor Theses

Eco-physiological adaptation and yield improvement of spring wheat under different water and nutrient management in the Loess Plateau, China

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The Loess Plateau of northwestern China is characterized by a semiarid climate where dry land farming has been practiced for four thousand years. The main crop in this region is wheat (*Triticum aestivum* L.); winter wheat is mainly cultivated in irrigated areas where water is relatively available, and spring wheat is mainly cultivated under rain-fed conditions. However, spring wheat production in the rain-fed agricultural areas is seriously limited by water shortage and soil nutrient deficiency due to severe water loss and soil erosion. To improve spring wheat productivity in this region, eco-physiological traits of drought resistance and effective cultivation techniques were investigated. The main research and results were as follows:

1. The effect of water stress simulated by polyethylene glycol on seedling establishment of two spring wheat cultivars, Hongmang and Mianyang 11, was tested. The growth of Mianyang 11 under water stress decreased more than that of Hongmang at all the stages of seedling establishment. This suggested that Hongmang was more drought tolerant than Mianyang 11. The critical water potential of the surrounding medium in which seedlings of the two cultivars could survive during seedling establishment was –1.05 MPa at plumule elongation stage. Therefore, plumule elongation was the most sensitive stage to water stress. At the beginning of germination under water stress, ATP concentrations in radicle of Hongmang increased more than that of Mianyang 11. This showed that ATP concentration associated with anabolism may be related to drought tolerance.

2. The effects of two water regimes on net photosynthetic rate (P_n), stomatal conductance (g_s), and intercellular CO_2 concentration (C_i) were investigated at the jointing, booting, anthesis, and grain filling stages of spring wheat cv. Dingxi 81-392. This is the most popular cultivar in the Loess Plateau. In comparison with control, low soil moisture invariably reduced P_n during the diurnal variations at all growth stages. P_n and g_s of plants in both soil moisture regimes was maximally reduced at midday. Atmospheric drought at midday decreased g_s, while C_i increased. This may suggest that the decrease in P_n at midday was not only related to stomatal closure but also to a reduction in photosynthetic activity of mesophyll.

3. To assess the effects of fertilization and planting density on the grain yield and water use efficiency (WUE) of spring wheat cv. Hongmang, field experiments were conducted for two years in the semiarid condition. The amount of fertilizer was highly and positively correlated with the grain yield and WUE, while planting density showed no correlation with these parameters. Application of fertilizer improved development of root system in the top 0-20 cm soil layer, which also led to increases in WUE and grain yield. The results also indicated that application of P and N increased biomass and grain yield, but the application of K had no effect on these parameters.

4. The effects of fertilization and supplemental irrigation at the jointing, heading and grain filling stages on plant growth, yield and WUE of spring wheat were also investigated. The result showed that leaf area, root dry mass and grain yield increased as the amount of fertilizer increased. Under the fertilized soil condition, supplemental irrigation at the jointing stage considerably increased kernel number per ear, kernel mass and grain yield. The optimal irrigated WUE was induced by supplemental irrigation at the rate of 60 mm. Supplemental irrigation at jointing stage ensured the most efficient use of soil water.

From this study on common spring wheat cultivars, it was observed that there were cultivar differences in drought tolerance during seedling establishment and midday depression of photosynthesis that may reduce grain yield under water stress conditions. It might be possible to take advantage of such knowledge for improving seedling establishment and grain yield under drought. The results from the different water and nutrient managements showed that application of N and P enhanced root growth and grain yield, and that supplemental irrigation at the rate of 60 mm during the jointing stage results in optimum WUE and increased grain yield. Therefore, effective fertilization and supplemental irrigation could lead to better use of limited water resources and increased wheat yield in semiarid areas.

Some Chemical and Physical Factors Affecting the Hydraulic Properties and Aggregate Stability of Sodic Soils

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It is of interest to inquire why the soil matrix responds in an adverse way to such a relatively small amount of exchangeable Na. An adsorbed Na percentage of 15 or less (and corresponding SAR) does not represent a very large fraction of the total exchange capacity that is occupied by Na, especially when we have observed that Ca and Mg dominate because of their divalent nature.

The effect of electrolyte concentration of percolating solution on hydraulic conductivity (HC) and infiltration rate (IR) of the Niigata smectitic and Tottori kaolinitic soils at Exchangeable Sodium Percentage (ESP) 0 and 30 was studied using soil columns and a rainfall simulator. The HC of the Niigata smectitic soil at ESP 0 reduced significantly with percolating distilled water (DW), whereas a decrease in HC at ESP 30 was observed with the 10 mol_c m^{-3} solution. The HC of the Tottori kaolinitic soil at ESP 30 dropped at the electrolyte concentration equal to or below the Flocculation Value (FV) of 5 mol_c m^{-3}. These results indicated that even for non-swelling clay soils a severe reduction in HC can be observed when the soil with a relatively high ESP level was exposed to solution at electrolyte concentration below the FV due to clogging of conducting pores by dispersed clay particles. The steady-state IR of the Niigata smectitic soil exposed to DW rainfall was strongly affected by the ESP, a much smaller effect of the ESP was observed for the Tottori kaolinitic soil. This was probably due to the fact that the aggregates are more stable than those of the Niigata smectitic soil at ESP 30. The lower steady-state IR for the soil at the higher ESP can be attributed to the higher FV of the soil at ESP 30. The ESP effect on steady-state IR was greater than that of HC when the soil was exposed to DW rainfall. This difference was probably due to the disintegration of soil aggregates and their compaction on soil surface caused by the impact of the raindrop.

A modified wet sieving method, based on ethanol-distilled water (DW) mixtures, was suggested for relative aggregate stability assessment of arid and semi-arid soils. The objectives of this study were (1) to modify the wet-sieving method by using ethanol-DW mixtures and (2) to evaluate aggregate size distribution as affected by clay content and adsorbed cation composition. Aggregates of sandy clay loam and clay soils were immersed in ethanol-DW mixtures at various ethanol concentrations or to NaCl and $CaCl_2$ solutions at total electrolyte concentration of 0.1 and 1 mol_c L^{-1}. Higher fraction of unstable aggregates was observed with ethanol-DW mixtures when the wetting rate was 100 mm h^{-1} than for 4 mm h^{-1}. Wetting rate is an important factor in aggregate stability determination even when ethanol was used. The stable 4-6 mm aggregates fraction decreased substantially in a relatively small range of ethanol concentration, having an inflection point at a stable aggregate fraction of 50 %. The ethanol concentration at the inflection point indicated the aggregate stability as function of clay content and exchangeable sodium percentage (ESP). The higher aggregate stability in the presence of ethanol is due to the reduction in the dielectric constant or due to by bridging of adjacent clay particles through ethanol molecule interaction. The disintegration of aggregate at higher electrolyte concentration indicated that the dominant reason in stabilizing larger aggregate was expected clay-ethanol molecule interaction.