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Model based assessment of barley root ideotypes for breeding strategies in water limited environments

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ABSTRACT

A simulation study of root effects on barley biomass production under Austrian and Iranian climate conditions was performed using the DAISY model. In Iran deep rooting cultivars provide a general advantage for crop growth. In Austria a rooting depth of 70 cm was sufficient to realize the year specific growth potential. Above a threshold of around 350 mm rainfall, competition for assimilates between roots and shoots even resulted in a lower biomass production of deep rooting cultivars.
KEYWORDS: drought, root ideotype, modeling, barley

1. INTRODUCTION

Drought tolerance is an increasingly important objective in plant breeding. Cultivars should combine high yield potential under optimum conditions and sufficient adaptation to stress. For this purpose an efficient water and nutrient uptake by the root system is crucial. There are many root traits that could potentially be selected for and target parameters may vary for different regions. Crop models may be a tool to assist plant breeding in defining promising root traits (Ho et al., 2004). Using the DAISY model (Hansen et al., 1990), our study analyses the growth performance of barley under different environmental conditions with varying root characteristics. The objective is to define environmental specific root ideotypes for improved drought tolerance.

2. MATERIAL AND METHODS

Two climatic situations were analyzed using ten years weather data from (i) a site in Eastern Austria near Vienna, and (ii) a site in West Iran at Sararood. Two soil types were tested, a silty loam (plant available water 180 mm m^{-1}) and a sandy loam (plant available water 100 mm m^{-1}). Simulations were made using the DAISY model which considers several root parameters to influence water uptake. The model calculates root water extraction by

$$S = L \cdot Q_r \qquad \text{and} \qquad Q_r = -r_r v(r) \int_0^{2\pi} f_c(\omega) d(\omega) \tag{1}$$

where S (m^3 m^{-3} s^{-1}) is the sink term, L (m m^{-3}) is root length density, Q_r (m^3 s^{-1} m^{-1}) is water uptake rate per unit root length, r_r (m) is root radius, $f_c(\omega)$ is a function for root-soil contact (0 no contact, 1 full contact), and v(r) (m s^{-1}) is the water flow velocity at the root surface. For our simulation analysis we varied (i) maximum rooting depth (range 0.5-1.1 m), (ii) root penetration rate (0.20-0.35 m d^{-1} $°C^{-1}$), and (iii) specific root length (70-130 m kg^{-1}). The effect on

aboveground dry matter production was analyzed by ANOVA. Subsequently regression relations between rainfall and biomass for the different rooting patterns were established.

3. RESULTS AND DISCUSSION

The two sites differ in rainfall amount and distribution. In Austria 49% of the average rain (542 mm) falls during the barley growth period, while in Iran it is only 36% of the total (436 mm). Besides the growing period rainfall is more erratic in Iran (CV=42%) than in Austria (CV=18%). The mean growth potential in Iran and Austria were 5.86 and 8.05 Mg ha^{-1}, respectively.

Results showed significant main effects of site, soil and root parameters on biomass production. Figure 1 shows the example of varying rooting depths for the sandy soil.

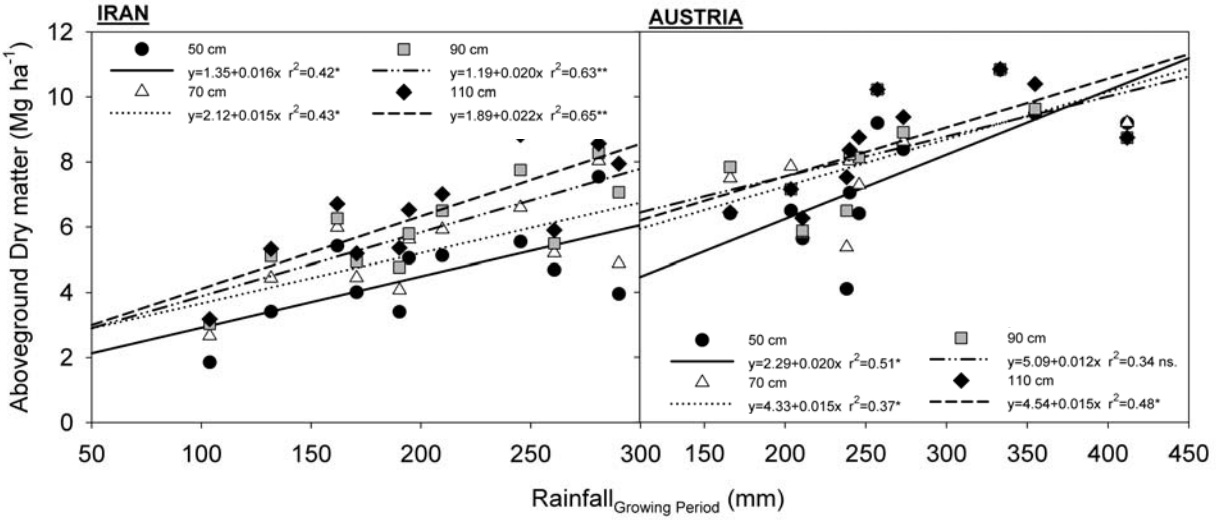

Figure 1. Relation between rainfall during the growing period of spring barley and biomass production for different rooting depths in a sandy soil.

In Iran an increasing rooting depth provides an advantage over the whole range of rainfall measured at the site. Due to fast water percolation to deeper layers in the sandy soil, this advantage increases towards higher rainfall. Austrian conditions show a disadvantage of shallow rooting (50 cm) only in dry years. In wetter years (rainfall > 350 mm) shallow rooting plants can even be an advantage due to lower biomass competition between above- and belowground parts.

4. CONCLUSION

Spring barley cultivars with a deep root system provided most advantage in sites where soil water reserves make up a high proportion of plant water supply (Iran), while in case of regular rainfall (Austria) a barley root system of 70 cm is sufficient to sustain the year specific growth potential.

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