Journal of Integrative Agriculture 2016, 15(7): 1595–1601

RESEARCH ARTICLE

Root carbon consumption and grain yield of spring wheat in response to phosphorus supply under two water regimes

GUAN Yu[1, 2], QIAO Zhen[2], DU Jiu-yuan[3], DU Yan-lei[2]

[1] *Department of Resource and Environmental Science, Agronomy College, Shihezi University, Shihezi 832000 P.R.China*
[2] *State Key Laboratory of Grassland Agro-ecosystem, Institute of Arid Agroecology, School of Life Sciences, Lanzhou University, Lanzhou 730000, P.R.China*
[3] *Institute of Wheat, Gansu Academy of Agricultural Sciences, Lanzhou 730070, P.R.China*

Abstract

In semiarid areas, cereal crops often allocate more biomass to root at the expense of aboveground yield. A pot experiment was conducted to investigate carbon consumption of roots and its impact on grain yield of spring wheat (*Triticum aestivum* L.) as affected by water and phosphorus (P) supply. A factorial design was used with six treatments namely two water regimes (at 80–75% and 50–45% field capacity (FC)) and three P supply rates (P1=0, P2=44 and P3=109 μg P g^{-1} soil). At shooting and flowering stages, root respiration and carbon consumption increased with the elevate of P supply rates, regardless of water conditions, which achieved the minimum and maximum at P1 under 50–45% FC and P3 under 80–75% FC, respectively. However, total aboveground biomass and grain yield were higher at P2 under 80–75% FC; and decreased with high P application (P3). The results indicated that rational or low P supply (80–75% of field water capacity and 44 mg P kg^{-1} soil) should be recommended to improve grain yield by decreasing root carbon consumption in semiarid areas.

Keywords: grain yield, phosphorus supply, root carbon consumption, spring wheat, water supply

1. Introduction

In semiarid areas, crop yields are usually reduced by low water and nutrient availability. In the Loess Plateau of China, total annual precipitation is varying from 200 to 700 mm. These conditions significantly restrict the productivity in natural and agricultural system (Wan *et al*. 2013; Guo and Li 2014). In addition, soil nutrients are easily oxidized and lost due to poor soil aggregate structure, resulting in poor nutrient availability or nutrient imbalances thus unsatisfying crop growth requirements (Zhou *et al*. 2012).

Plants prefer to allocate a greater proportion of carbon to the root system in cases of limited resources (Poorter *et al*. 2012; Fan *et al*. 2015), which fits with the 'functional equilibrium' theory that plants adjust the allocation of biomass to roots and shoots depending on the environment (nutrition, water and light) (De Willigen and Van Noordwijk 1987). In semiarid areas, crops tend to evolve large root systems with increased surface area and volume for acquiring more resources, such as water and nutrients (Zhang *et al*. 1999; Fang *et al*. 2010); however, the large root system aggravates excess consumption of photosynthesis assimilates

---

Received 17 June, 2015 Accepted 9 October, 2015

Correspondence DU Yan-lei, Tel/Fax: +86-931-8912848,
E-mail: yanleidu@lzu.edu.cn

doi: 10.1016/S2095-3119(15)61193-5

and soil water which is unfavorable to grain production (Ma *et al*. 2008, 2010). Passioura (1983) proposed that if carbon consumption of roots decreased, crops under water stress will maintain a positive carbon balance and more assimilates will be released for grain production. Du *et al*. (2012, 2013) has found that the new breeding spring wheat cultivar in Loess Plateau with small root size benefit its grain yield under drought condition. However, information on the relationship between carbon consumption and grain yield of spring wheat under limited water and phosphorus (P) supply-condition is till meager.

In order to increase grain yields in water-limited areas, regulating carbon allocation of crops through optimizing water and P management is very important. A pot experiment with spring wheat (*Triticum aestivum* L.) was conducted to determine (i) the response of carbon consumption of wheat roots to different water and P treatments; (ii) the different impacts of water and P on wheat yield and water use efficiency; and (iii) the relation of carbon consumption of roots and grain yield.

2. Materials and methods

2.1. Experimental conditions

The experiment was conducted at the Yuzhong Experimental Station of Lanzhou University in Yuzhong County in China (35°51´N, 104°07´E, altitude 1620 m above sea level) from March to July of 2007. The experimental site was representative of the semi-arid climate in northwestern China, with 329 mm rainfall, 1703 mm evaporation, 14.2°C mean temperature, and 58% relative humidity during the growing season. The spring wheat cultivar Longchun 8275 was used in the present experiment, which was widely adapted in the semiarid regions of the Loess Plateau of China. Each non-drained plastic pot (260 mm diameter×300 mm high) was filled with 8.5 kg 1:5.2 (v/v) mixture substrate of vermiculite and loess soil (Calcic Kastanozems, FAO). In order to avoid or decrease the impact of soil original P, the soil was collected from 2 m below ground. The soil was a loess-like loam with a pH of 8.3, inorganic N of 0.10 μg g^{-1} soil, available P of 3.5 μg g^{-1} soil, K of 86.9 μg g^{-1} soil and organic matter of 6.2 g kg^{-1}. Mixture substrates were air dried and passed through a 2-mm sieve. Before sowing, N (2.54 g N as NH_4NO_3) and K (2.91 g K as K_2SO_4) were applied to each pot so that the nutrition was not limited. Phosphorus added as $Ca(H_2PO_4)_2\cdot H_2O$ was ground to powder, mixed with the above mentioned mixture substrate in an end-over-end shaker and applied to the soil in rates of 0 (P1), 44 (P2) and 109 (P3) μg P g^{-1} dry soil. Twenty-five seeds were sown in each pot on late March, and thinned to 16 plants after germination. After thinning, all plants were irrigated on a daily basis with deionized water to maintain the soil moisture content at 80–75% field capacity (FC) until commencement of further water treatments. Water treatments were imposed from trefoil stage to maturity at 80–75% and 50–45% FC, respectively. The experiment comprised of 54 pots in total (three replications for each water and P fertilizer combination at three harvest stages) and plants were grown in a rainout shelter (50 m long×24 m wide×5.7 m high) that was closed during rain events. Additionally, 18 pots without planting (three replications for each water and P fertilizer combination treatment) were used to measure soil microbial respiration.

2.2. Data sampling

Plant height and total leaf areas were measured at shooting (55 days after sowing (DAS)) and at flowering (71 DAS). The length and width of individual leaves of two plants in each pot was recorded to calculate the total leaf areas per plant. Total leaf areas per plant is the sum of individual leaf area, which was calculated as:

Leaf area=Length×Width×0.83

After measuring plant height and total leaf areas, the plant and soil were harvested destructively to determine carbon consumption of root. According to Kelting *et al*. (1998), a combination of excised-root respiration method and basal respiration method was used to estimate three components of whole-soil respiration. Shoots were cut off at soil level before root respiration measurements. After excision, all roots were taken out and immediately measured using an infrared gas analyzer (LI-6400, Li-Cor, Inc., Lincoln, NE, USA) for total soil respiration (R_{total}, mg CO_2 m^{-2} h^{-1}). The roots were hand-washed to remove soil debris, blotted dry to remove surface water and placed into a cuvette in a temperature-controlled room (25°C) to equilibrate 30 min, and then measured for root respiration (R_{root}, mg CO_2 plant^{-1} h^{-1}). To account for soil microbial respiration (R_{mic}, mg CO_2 plant^{-1} h^{-1}), the gas fluxes from bare soil were measured. Rhizosphere microbial respiration (R_{rhizo}, mg CO_2 plant^{-1} h^{-1}) was calculated as:

$R_{rhizo}=R_{total}-R_{root}-R_{mic}$

After respiration measurements, root tissue was dried and weighed for assessing root dry mass. The specific root respiration and specific rhizosphere microbial respiration (mg CO_2 plant^{-1} h^{-1} g^{-1}) were defined as CO_2 generated by root respiration and rhizosphere microbial respiration per unit root dry mass and per unit time, respectively.

The soil CO_2 effluxes was sampled during 09:00–11:30 a.m. because soil respiration rate during this time interval was reported to be close to daily means and not changed (Janssens *et al*. 1998; Tang *et al*. 2006).

The belowground carbon allocation of crops (C_{total}) mainly