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Full Length Research Paper

The relationship between root traits and aboveground traits in peanut (*Arachis hypogaea* L.)

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Data of 12 peanut varieties were analyzed with a view to investigate the relationship between root traits and aboveground traits. Results showed that root biomass was positively correlated with aboveground biomass and total biomass at three stages of growth and development. Root activity at different growth stages were significantly and positively correlated with yield at the mature stage. However, a significant negative correlation was observed between yield and root/shoot ratio at the mature stage. It was concluded that the root system possessed a close relationship with aboveground parts, and keeping the root activity of peanut at the mature stage was essential for achieving high and stable yield.

Key words: Peanut, root traits, aboveground traits, correlation.

INTRODUCTION

Root system is an important organ of plants for absorbing water and nutrition and synthesizing chemicals like hormones. It plays an important role in the development of aboveground organs and yield formation (de Dorlodot et al., 2007). Although, the root system has long been noticed and studied, progress remains slow and limited as compared with aboveground organs due to a massive volume of work and limitations of research methods. So far, studies on the root system of peanut have been mostly focused on variation in root morphology under different environments, root characteristics among different varieties and inheritance of root traits (Meisner and Karnok, 1992; Liao et al., 2000, 1992; Ren et al., 2006a, 2007). Ren et al. (2006b, 2007) investigated eleven root traits in a peanut RIL population and found that all the traits showed consistent genetic variation and transgressive segregation. Genetic analysis revealed that most root traits showed low heritability and were controlled by multiple genes. Moreover, gene interaction occurred in some root traits, such as in length of axial root and thickness of root base, nodule number of lateral root and dry weight of lateral root. Liao et al. (2000) found that Al-tolerant varieties of peanut have large root volume and dry weight. Under Aluminium stress, yield had the largest correlation coefficient with root volume. Large root system was considered as an important index for selecting Al-tolerant variety. Moreover, the contribution of root hairs to phosphorus (P) uptake was studied and the result indicated that the ability to form hairs on roots and gynophores can be seen as an adaptation to low P availability and if combined with a large root system, it could substantially increase the tolerance of peanuts to P deficiency (Wissuwa and Ae, 2001). In summary, to our knowledge, the relationship between root system and the aboveground parts in peanut has not yet been sufficiently studied. The purpose of this study was to analyze the correlation between root traits and aboveground traits in peanut.

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MATERIALS AND METHODS

12 peanut varieties (Yueyou 7, Yueyou 13, Yueyou 256, Yueyou 14,

Table 1. Correlation between root traits and aboveground traits at the flowering and fruiting stages.

Characteristics	Root volume		Root biomass		Root/shoot ratio		Root activity	
	I	II	I	II	I	II	I	II
Plant height	0.914**	0.326	0.903**	0.542	0.339	-0.128	0.841**	0.257
Branch number	-0.478	0.138	-0.571	-0.237	-0.327	0.457	-0.517	-0.284
Green leaf number of main stem	-0.412	0.487	-0.437	0.204	0.105	0.644*	-0.462	-0.469
Aboveground biomass	0.886**	0.459	0.891**	0.627*	0.481	-0.371	0.836**	-0.083
Total biomass	0.907**	0.476	0.932**	0.678*	0.502	-0.314	0.871**	-0.118

1) I = Flowering stage, II = Fruiting stage; $r_{(10, 0.05)} = 0.576$, $r_{(10,0.01)} = 0.708$.

Pearl Red 1, Zhongkai Hua 1, Zhongkai Hua 4, Shanyou 42, Shanyou 523, Zhanyou, Zhanyou 26, Zhanyou 62, and Zhanyou 55) were cultivated and used for correlation analysis. These varieties were provided by Guangdong Academy of Agricultural Sciences (GDAAS), China.

Field experimental design

Field experiments were conducted at the GDAAS farm. The 12 peanut varieties were cultivated on March 5th 2011 using a Completely Randomized Design (CRD) with three replicates of each variety with single seed sowing. Spacing between rows was 25 cm and within-row spacing was 20 cm. Area of each plot was 15 m^2. Fertilizer inputs were 50 kg N/ha, 30 kg P/ha and 80 kg K/ha.

Measurement of root and aboveground traits

Every three plants were randomly selected from each plot at the flowering stage, the fruiting stage and the mature stage respect-tively. Plants were thoroughly dug out from the root level. All the roots were washed clean of any soil and organic matter using a 2 mm sieve. The root and aboveground traits were measured, inclu-ding plant height, branch number, total biomass, aboveground biomass, root biomass, root volume, root length and root activity. Root volume was measured by water displacement method (Zhang, 1998a); root activity was evaluated by triphenyl tetrazolium chloride (TTC) method for visualizing the activity points of succinic acid dehydrogenase related with respiratory system (Zhang, 1998b). Ten plants were randomly selected from each plot at the mature stage for investigation of the following yield-related traits; yield, green leaf number on the main stem, number of pods per plant, percentage of well-developed pods, weight per 100 pods and percentage of double-seeds.

Data analysis

Statistical analysis was performed with the SPSS 17.0 software package. Statistical significance was defined as a 2-sided P-value of 0.05 or less.

RESULTS

Correlation analysis of root and aboveground traits

Flowering stage

At the flowering stage, the root traits (volume, biomass and activity) were significantly (P≤0.01), positively corre-lated with the aboveground traits (plant height, above-ground biomass, total biomass), but were not correlated with green leaf number on the main culm and branch number. No significant correlations were found between root/shoot ratio and the aboveground traits (Table 1). Furthermore, correlation between root activity at the flowering stage and yield at the mature stage were analyzed and a significant positive correlation (r = 0.589) was observed. These results indicated strong asso-ciations between the root traits at the flowering stage and the aboveground traits.

Fruiting stage

As shown in Table 1, the correlations between root traits and aboveground traits at the fruiting stage were different with those at the flowering stage. Root biomass was significantly correlated with aboveground biomass and total biomass, but was not correlated with the other aboveground traits. In addition, no significant correlations were found between root traits (root volume and root activity) and any aboveground traits. Contrary to the correlation analysis at the flowering stage, root/shoot ratio at the fruiting stage was significantly and positively correlated with green leaf number on the main culm. It is noteworthy that root activity at the fruiting stage still maintained a significant positive correlation (r = 0.700) with yield.

Mature stage

The result of correlation analysis between root and aboveground traits at mature stage was shown in Table 2 and 3. Both root volume and root length was significantly (p≤0.01) correlated with plant height and leaf number on the main culm. Root biomass was highly significantly (p≤0.01) correlated with plant height, green leaf number of main stem and total biomass, and significantly (p≤0.05) correlated with aboveground biomass. Root/shoot ratio was significantly, positively correlated with branch number, while a significant negative correlation was

Table 2. Correlation between root and aboveground traits at the mature stage.

Characteristics	Root volume	Root biomass	Root length	Root/shoot ratio	Root activity
Plant height	0.881**	0.855**	0.839**	0.264	-0.558
Branch number	0.504	0.269	-0.036	0.682*	-0.224
Green leaf number on the main culm	0.847**	0.856**	0.781**	-0.261	0.841**
Aboveground biomass	0.514	0.706*	0.131	-0.513	0.683*
Total biomass	0.541	0.731**	0.153	-0.487	0.670*
Number of pods per plant	0.142	-0.161	-0.265	0.441	-0.215
Percentage of well-developed pods	0.311	0.002	0.422	-0.119	0.124
Weight per 100 pods	-0.208	-0.233	0.156	0.109	-0.117
Percentage of double-seeds	0.284	0.329	0.101	-0.035	0.189
Yield	-0.202	0.036	-0.263	-0.657*	0.687*

1) $r_{(10, 0.05)} = 0.576$, $r_{(10,0.01)} = 0.708$.

Table 3. Root activity and yield components of different varieties.

Variety	Root activity/(mg g^{-1} h^{-1})			No. of pods per plant	Percentage of well-developed pods (%)	Percentage of double seeds (%)	Weight per100 pods (g)	Yield ($kg.hm^{-2}$)
	Flowering stage	Fruiting stage	Mature stage					
Yueyou 7	88.3	181.2	47.8	14.7	79.6	85.2	194.5	4543.5
Yueyou 13	89.2	170.4	43.2	13.7	77.2	78.0	194.8	4309.5
Yueyou 256	80.4	142.3	40.1	14.1	81.3	80.3	146.6	3322.5
Yueyou 14	86.9	163.5	44.3	13.8	82.3	81.0	166.4	4063.5
Peral Red 1	85.4	91.2	25.3	13.0	80.1	83.2	175.8	3832.5
Zhongkai Hua 1	88.4	146.8	39.2	14.1	77.5	80.0	176.1	4054.5
Zhongkai Hua 4	74.5	82.4	23.1	15.6	73.6	80.4	213.8	3003.0
Shanyou 42	89.3	133.6	30.8	13.6	81.4	77.1	168.2	3648.0
Shanyou 523	80	137.2	35	13.8	85.2	83.8	170.6	3754.5
Zhanyou 26	72.4	110.3	31.2	17.1	85.0	79.3	156.2	3949.5
Zhanyou 62	83.8	137.6	36.9	14.8	82.4	81.2	160.4	4182.0
Zhanyou 55	86.8	143.6	38.4	14.1	79.0	82.0	185.4	4219.5

observed between root/shoot ratio and yield. Root activity was significantly, positively correlated with aboveground biomass, total biomass and yield. Moreover, a highly significant correlation was found between root activity and green leaf number on the main culm.

Relationship between root activity and yield

Relatively high root activity was observed at the flowering stage with little variation among the varieties Table 3 . At the fruiting stage, root activities reached the highest and demonstrated high variation among the varieties. The maximum activity (181.2 mg.g^{-1} h^{-1}) was observed in Yueyou 7, which was almost double that of Pearl Red 1 with the minimum activity (91.2 mg.g^{-1} h^{-1}). Root activity at the mature stage dropped to the lowest levels with a large variation among the varieties. For example, the root activity in Zhongkai Hua 4 was 23.1 mg g^{-1} h^{-1}, which is less than half of that in Yueyou 7 (47.8 mg g^{-1} h^{-1}). For all the three stages, root activity demonstrated significant positive correlation with yield, which indicated that root activity made a critical contribution to yield. The high-yielding varieties, Yueyou 7, Yueyou 13 and Yueyou 14 maintained high root activity at the stages of growth and development. The root activity of the three varieties at the mature stage were 47.8, 43.2, 44.3 mg g^{-1} h^{-1} respectively, which were significantly higher than that of Zhongkaihua 4 which had the lowest root activity and yield.

DISCUSSION

The ability of crops to absorb water and nutrients is closely associated with root morphological traits. Hence, selecting varieties with desirable root morphological traits can be an effective way to expand their ability to acquire water and nutrients. This study revealed that except for the root/shoot ratio at the flowering time, the other root traits of peanut were significantly, positively correlated with at least one of the aboveground traits at all three growth and development stages. The close relationship between root system and aboveground organs not only existed in peanut, but also in the other crop. Shi et al. (1997) measured twelve traits of rice varieties with different panicle types and found that the number of adventitious roots, the total root weight and the diameter of nodal roots were closely correlated with some of aboveground traits. Similar phenomena also occurred in soybean (Yang et al., 2002). Since the root traits had big contributions on yield in crop, they received increasing attention by crop breeders (Steele et al., 2006).

Compared with aboveground parts, the same amount of accumulated biomass in roots will cost twice as much as energy due to the long distance transportation of photosynthesis. Therefore, under sufficient water condition, too large root volume will negatively affect dry matter accumulation in the aboveground parts, whereas properly reduced root volume will be more propitious to high yield (Passioura, 1983). This hypothesis was supported in this study by the negative correlation coefficients between root/shoot ratio and aboveground biomass, total biomass, yield at mature stage, especially, among which the root/shoot ratio and yield was significantly, negatively correlated. The result indicated that proper reduction of root/shoot ratio of peanut would have no negative effect on yield, but may promote dry matter accumulation in aboveground parts to some extent. However, such relationship may change under dry stress, where large root system had the ability to uptake more water to support growth and resulted in higher yield (Liao et al., 2001). Therefore, water condition should be taken into account in selecting peanut varieties based on root traits.

Previous studies have demonstrated that delaying leaf senescence in mature stage could improve dry matter accumulation and yield formation (Paul and Pellny, 2003; Walter and Schurr, 2005; Gregersen et al., 2008). Furthermore, leaf senescence was closely related to root activity (Yue et al., 1996; Schachtman and Goodger, 2008). Once root activity was inhibited during stressed condition, leaf senescence would be accelerated, whereas increase in root activity would delay leaf senescence. In the present study, the root activity in mature stage were significantly, positively correlated with green leaf number on the main stem and yield, which indicated that root activity of peanut in mature stage played an essential role in achieving high and stable yield.

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