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Rooting traits of peanut genotypes with different yield responses to terminal drought

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ABSTRACT

Drought at pod filling can severely reduce yield of peanut. Better root systems can reduce yield loss from drought. However, the relationship of root characters with yield under terminal drought is not well understood. The objective of this study was to investigate the responses of peanut genotypes with different yield responses to terminal drought stress for root dry weight and the percent root length density (% RLD) in deeper soil layers and their relationships with biological and economic yield. A field experiment was conducted at Khon Kaen University's Agronomy Farm in 2010/2011 and 2011/2012. A split plot design with four replications was used in this study. Five peanut genotypes: ICGV 98308, ICGV 98324, ICGV 98348, Tainan 9 and Tifton 8 were assigned as subplots and two soil moisture levels [field capacity (FC) and 1/3 available water (1/3 AW) at R7 growth stage through harvest] were assigned as main plots. Data for root dry weight, % root length density (% RLD), stomatal conductance, water use efficiency (WUE), pod yield, biomass, harvest index (HI), were recorded at harvest. Drought significantly reduced pod yield, biomass and HI. Overall genotypes, yield responses to terminal drought were not correlated with root dry weight and % RLD. However for some genotypes, yield under terminal drought did seem to be related to root dry weight and % RLD. The genotypes with large root system and high stomatal conductance, WUE and biomass and maintained higher pod yield under terminal drought. For example, Tifton 8 had high root dry weight and high stomatal conductance, WUE and biomass, maintained higher pod yield under drought conditions. Peanut genotypes that have high % RLD at deeper layers and high stomatal conductance, WUE and HI might also maintain pod yield under terminal drought. ICGV 98324 and ICGV 98348 increased % RLD at deeper layers and also had high stomatal conductance, WUE and HI and maintained higher pod yield under terminal drought. Percent RLD could be useful as a selection criterion for improving resistance to drought. However, selection of RLD alone can be confounded because some genotypes with high RLD under terminal drought had low pod yield, and selection of RLD as a supplement for pod yield under drought would be more effective.

1. Introduction

Peanut (*Arachis hypogaea* L.) is a major legume in many developing countries, and it is widely cultivated in the semi-arid tropics (Latha et al., 2007). In areas with very low rainfall and uneven rain distribution, peanut is likely to suffer from drought that affects growth, development, pod yield and product quality. Drought during late growth stages not only affects peanut productivity but also increases *A. flavus* colonization and aflatoxin contamination (Diener et al., 1987; Girdthai et al., 2010a). Yield reductions of 56–85% were recorded when peanut was exposed to drought at seed-filling stage (Del Rosario and Fajardo, 1988; Nageswara Rao et al., 1985), and yield reduction of 24% was reported when the crop was subjected to drought at the end of growing season (Boontang et al., 2010).

Access to sufficient irrigation can alleviate problems from drought. However, high investment is required and water is often insufficient because of competition for water with the industrial sector and urban consumption. When drought resistant varieties are available, the use of these varieties is a good and sustainable choice (Girdthai et al., 2010a; Songsri et al., 2008b). Breeding of peanut for resistance to late season drought requires information on morphological and physiological responses of peanut to drought and the mechanisms underlying the adaptability of

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the crop to minimize yield loss. Most studies have reported on the response of physio-morphological characters of above ground plant components (Arunyanark et al., 2008; Girdthai et al., 2010a; Puangbut et al., 2010), but there is limited information for root characteristics. Previous research has documented root traits under long-term drought conditions (Songsri et al., 2008b), early drought conditions (Jongrungklang et al., 2011) and mid-season drought (Jongrungklang et al., 2012), but they did not focus on terminal drought.

Root traits associated with drought tolerance are important for identifying drought resistant mechanisms of plants. Root characteristics such as deep rooting, root length density (RLD) and root distribution have been identified as drought adaptive traits that can be used as selection criteria for drought resistance (Matsui and Singh, 2003; Taiz and Zeiger, 2006; Turner, 1986). Peanut genotypes with higher root length density in the deeper soil layers potentially have an enhanced drought tolerance and this could aid peanut genotypes to obtain higher pod yield and harvest index under long-term drought conditions (Songsri et al., 2008b). There was a tendency of greater average RLD at the 30–90 cm soil profile in the group of genotypes that were subjected to pre-flowering drought, and RLD remained high even after re-watering, resulting in increased pod yield (Jongrungklang et al., 2011). Large root system can maintain high plant water status and yield during drought stress (Rucker et al., 1995), and the ability of a plant to change its root distribution in the deeper soil water was an important mechanism for drought avoidance (Benjamin and Nielsen, 2006).

Root response to drought is another mechanism enhancing drought resistance as roots penetrate deeper into the drying soil to mine more water (Ludlow and Muchow, 1990; Taiz and Zeiger, 2006). Girdthai et al. (2010b) observed that peanut genotypes were different in tolerance to late season drought possibly due to the differences in root responses of these peanut genotypes. If this is the case, root response to late season drought might be a factor contributing to higher yield under drought. However, this hypothesis has not been tested elsewhere.

Root responses at pre-flowering (Jongrungklang et al., 2011) at mid-season drought (Jongrungklang et al., 2012) and long-term drought (Songsri et al., 2008b) were reported previously by our research project. Root response at the late period of growth stages can be an important mechanism to maintain high yield, and the character may be used as a selection tool for drought tolerance in peanut. The information on this trait is very scant in the literature and further investigations are required. As the continuation of previous studies, this study focuses on root response to terminal drought and will complete the responses of root for all drought conditions. Therefore, the goal of this study was to investigate the responses of root dry weight and % RLD of peanut genotypes having different yield responses to terminal drought stress and their relationships with biological and economic yield.

2. Materials and methods

2.1. Experimental details

The experiment was conducted under field conditions at the Field Crop Research Station of Khon Kaen University, Thailand (latitude 16° 28 N, longitude 102° 48 E, 200 m above sea level) during the dry season 2010/2011 and repeated during the dry season 2011/2012. Experimental design was a split-plot with four replications. Main-plot treatments were two soil moisture levels [field capacity (FC) and 1/3 available water (1/3 AW) at R7 growth stage through harvest] and sub-plot treatments were 5 peanut genotypes. Plot size was 5 m × 5 m with spacing of 50 cm between rows and 20 cm between plants within a row. Rainout shelters were available if necessary.

Five peanut genotypes used in this study were ICGV 98308, ICGV 98324, ICGV 98348, Tainan 9 and Tifton 8. The accessions with ICGV number are elite drought resistant lines obtained from ICRISAT (Nageswara Rao et al., 1994; Nigam et al., 2003, 2005). The ICGV accessions were also identified as drought resistant genotypes in our previous work (Girdthai et al., 2010a). Tainan 9 is a Spanish-type peanut cultivar having low drought tolerance index (DTI = trait at drought stress/trait at non-stress) (Girdthai et al., 2010a) and low dry matter (Vorasoot et al., 2003). Tifton 8 (Coffelt et al., 1985) is a drought resistant Virginia-type line with a large root system received from the United States Department of Agriculture (USDA). Girdthai et al. (2010a) observed that ICGV 98324 and ICGV 98348 had high DTI for total biomass and pod yield, Tifton 8 exhibited the highest biomass production but reductions in pod yield was also high, Tainan 9 and ICGV 98308 had high reduction in total biomass and pod yield under terminal drought.

2.2. Crop management

Soil was ploughed three times and triple superphosphate at the rate of 122 kg ha^{-1} and potassium chloride at the rate of 62 kg ha^{-1} were incorporated into the soil during soil preparation. Seeds were treated with captan (3a,4,7,7a-tetrahydro-2-[(trichloromethyl) thio]-1H-isoindole-1,3 (2H)-dione) at the rate of 5 g kg^{-1} seeds and seeds of Tifton 8 were treated with ethrel 48% at the rate of 2 ml l^{-1} water to break dormancy. Three seeds were planted and later the seedlings were thinned to obtain one plant per hill at 14 days after planting (DAP). *Rhizobium* inoculation was done by applying a water-diluted commercial peat-based inoculum of *Bradyrhizobium* (mixture of strains THA 201 and THA 205; Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand) on the rows of peanut plants after planting, and then water was applied to the level of field capacity (FC). Weeds were controlled by an application of alachlor (2-cholro-2′,6′-diethyl-*N*-(methoxymethyl) acetanilide 48%, w/v, emulsifiable concentrate) at the rate of 3 l ha^{-1} at planting and hand weeding.

Gypsum ($CaSO_4$) at the rate of 312 kg ha^{-1} was applied at 40 days after emergence (DAE). Carbofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-ylmethylcarbamate 3% granular) was used at the pod setting stage (60 DAE) to protect the crop from ants and other insects. Pests and diseases were controlled by weekly applications of carbosulfan [2-3-dihydro-2,2-dimethylbenzofuran-7-yl (dibutylaminothio) methylcar-bamate 20% (w/v), water soluble concentrate] at 2.5 l ha^{-1}, methomyl [*S*-methyl-*N*-((methylcarbamoyl)oxy) thioacetimidate 40% soluble powder] at 1.0 kg ha^{-1}, dicophol [2,2,2-trichlor-1,1-bis c4-chlorophenyl ethanol 18.5%, w/v, emulsifiable concentrate] at the rate of at 2.5 l ha^{-1} and carboxin [5,6-dihydro-2-methyl-1,4-oxathine-3-carboxanilide 75% wettable powder] at the rate of 1.68 kg ha^{-1}.

2.3. Water management

A subsurface drip irrigation system (Super typhoon®; Netafim Irrigation Equipment & Drip systems, Tel Aviv, Israel), a distance of 20 cm between emitters was installed with a spacing of 50 cm between drip lines at 10 cm below the soil surface midway between peanut rows, and fitted with a pressure valve and water meter to ensure uniform supply of measured amounts of water across each plot. Sub-valves were set up at each sub-plots of water stress plots to control the required water amounts for each genotype according to the predetermined water level (1/3 AW) at their individual growth stages. Soil water level was maintained