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Determination of coefficient defining leaf area development in different genotypes, plant types and planting densities in peanut (*Arachis hypogeae* L.)

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ABSTRACT

Rapid leaf area development may be attractive under a number of cropping conditions to enhance the vigor of crop establishment and allow rapid canopy closure for maximizing light interception and shading of weed competitors. This study was undertaken to determine (1) if parameters describing leaf area development varied among ten peanut (*Arachis hypogeae* L.) genotypes grown in field and pot experiments, (2) if these parameters were affected by the planting density, and (3) if these parameters varied between Spanish and Virginia genotypes. Leaf area development was described by two steps: prediction of main stem number of nodes based on phyllochron development and plant leaf area dependent based on main stem node number. There was no genetic variation in the phyllochron measured in the field. However, the phyllochron was much longer for plants grown in pots as compared to the field-grown plants. These results indicated a negative aspect of growing peanut plants in the pots used in this experiment. In contrast to phyllochron, there was no difference in the relationship between plant leaf area and main stem node number between the pot and field experiments. However, there was genetic variation in both the pot and field experiments in the exponential coefficient (PLAPOW) of the power function used to describe leaf area development from node number. This genetic variation was confirmed in another experiment with a larger number of genotypes, although possible G × E interaction for the PLAPOW was found. Sowing density did not affect the power function relating leaf area to main stem node number. There was also no difference in the power function coefficient between Spanish and Virginia genotypes. SSM (Simple Simulation model) reliably predicted leaf canopy development in groundnut. Indeed the leaf area showed a close agreement between predicted and observed values up to 60000 cm^2 m^{-2}. The slightly higher prediction in India and slightly lower prediction in Niger reflected GxE interactions. Until more understanding is obtained on the possible GxE interaction effects on the canopy development, a generic PLAPOW value of 2.71, no correction for sowing density, and a phyllochron on 53 °C could be used to model canopy development in peanut.

1. Introduction

Crops produce leaves to intercept light, use intercepted light energy to synthesize mass, and partition mass into grain. Rapid establishment of leaf area also allows for diminished water evaporation from the soil surface and for shading of an emerging weed. To understand leaf area development, allometric relationships have been developed in many crops between leaf node number and plant leaf area during the major phase of leaf area development (Sinclair, 1984; Robertson et al., 2002; Soltani et al., 2006). In crop simulations, total plant leaf area (PLA) is then calculated as an empirical function of main stem node number. The crop model APSIM first

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estimates the effective leaf number for the entire plant based on main stem node number (Hammer et al., 1995; Robertson et al., 2002). The specific steps in this approach are calculation of: (1) node number on main-stem based on cumulative temperature, (2) total plant leaf number from main stem node number, (3) fraction of senesced leaf number on main stem based on cumulative temperature, (4) plant senesced leaf number from main stem senesced leaf number, (5) green leaf number from total and senesced leaves, (6) individual leaf size from main stem node number or cumulative temperature (assumed to be constant 40 cm^2 in peanut), (7) PLA as the product of total leaf number per plant and individual leaf size, (8) leaf area index (LAI) from plant leaf area and plant density. Clearly, this method requires several functions and a number of defined coefficients. An alternative proposed by Soltani and Sinclair (2012) in the model SSM (Simple Simulation Model) is to avoid the assumption about individual leaf area by simply calculating plant leaf area directly from an empirical function based on main stem node number. Therefore, this simpler approach requires only three steps by calculating: (1) main stem node number from cumulative temperature, (2) PLA from main stem node number [in this step density effect is considered], (3) LAI from PLA and plant density. This simplified approach requires fewer parameters than the APSIM method, which may allow easier experimental evaluation of parameters. In addition, it includes a specific target parameter for considering a plant density effect. It is this simpler model we use here to evaluate PLA development in several peanut genotypes.

Under non water stressed conditions, the rate of node number appearance on the main stem is based on daily temperature units, which is commonly calculated as the difference between daily mean temperature and a base temperature. The cumulative temperature units (cumulated °C or °C) required for the production of successive nodes on the main stem is defined as the phyllochron. In peanut, node production on the main stem starts after plant emergence and continues up to final harvest with slower development after the appearance of the 17th node (Forestier, 1969). Leong and Ong (1983) found a decrease in the rate of node number appearance, or leaf appearance rate, under drought conditions with a base temperature up to 11.4 °C. Young et al. (1979) reported for peanut (*Arachis hypogaea* L.) that the base temperature for leaf appearance among several genotypes was 10° C, meaning that there was no leaf development below this temperature. Peanut base temperature can also vary with botanical type. Bagnall and King (1991) identified different phenological base temperatures for Spanish genotypes (13.6 °C), Valencia genotypes (12.6 °C) and Virginia genotypes (11.4 °C). Mohamed (1984) found that base temperature for peanut ranged from 8 to 11.5 °C in experiments with maximum temperature ranging from 29 to 36.5 °C. Most of peanut models of leaf development (Fortanier, 1957; Ong, 1986; Boote et al., 1989) use 11 °C as a generic base temperature, and this is the base temperature used by the model in this work. The daily temperature units increase linearly above the base temperature up to the optimum temperature, which is often assumed to be 28 °C in peanut.

A key question in crop improvement is whether genetic variability exists in the parameters describing leaf area increase. That is, is there genetic variability that might be exploited to breed for altered rate of leaf area development? For example, in environments with available water it could be advantageous to have rapid leaf area development to allow early crop vigor and to shade weed competitors. In studies of phyllochron diversity, Dofing (1999) found in barley (*Hordeum vulgare* L.) a range among genotypes of 52 to 70 °C and Rebolledo et al. (2012) found in rice (*Oryza sativa* L.) a range of about 45 to 71 °C. On the other hand, van Esbroeck et al. (2008) reported little variation in phyllochron across a diverse panel of maize genotypes. The same observation was found in some cereals where phyllochron was found to be almost constant from seedling stage to flag-leaf expansion in sorghum (*Sorghum bicolor* L.) (Muchow and Carberry, 1990; Craufurd et al., 1998; Clerget et al., 2008), millet (*Pennisetum glaucum* L.) (Craufurd and Bidinger, 1988), maize (*Zea mays* L.) (Birch et al., 1998). Sinclair (1984) also found that the phyllochron was constant with variation of base temperature among soybean (*Glycine max* (L.) Merr.) genotypes. Leong and Ong (1983) and Craufurd et al. (1997) reported that the phyllochron was stable across environments for single genotypes of peanut (56 °C). There appears to be no information on the genetic variation in peanut for phyllochron and the calculation of plant leaf area. Therefore, a major objective to this investigation was to document the variation in leaf area parameters across ten peanut genotypes of diverse genetic background, including a comparison of Spanish and Virginia types.

Another key question was whether plant density affects leaf area development in peanut, and can this be described in the proposed parameters describing leaf area development. In peanut, a recommended seeding rate of 60 kg ha^{-1} is common in Africa and this leads to a density of approximately 15–20 plant m^{-2}. In India higher sowing density is used resulting in greater than 30 plant m^{-2} and in Australia 6.5 to 7.5 plants m^{-2} (Virginia-type) and >22.5 plants m^{-2} for (Spanish-type) (Bell et al., 1991). It was previously reported (Giayetto et al., 1998) in peanut (runner and erect types) that increased plant density resulted in a decrease in individual PLA and plant dry matter. These decreases were attributed to greater intraspecific competition produced by the shortening of distances between rows. A study in four Virginia type cultivars showed that an increased plant density led to increased vegetative development and more numerous reproductive organs, although this did not led to higher yield because of indeterminacy in pod setting (Cahaner and Ashri, 1974). On the contrary a study in two Virginia type cultivars showed no increase in the vegetative growth and yield at higher density (Tewolde et al., 2002). In any case, none of these studies generated the data necessary to quantitatively evaluate the parameters in the functions proposed to describe PLA or a range of peanut genotypes and plant densities.

Therefore, the objectives of this work were to quantify PLA development in peanut and use the derived parameters to assess possible genetic variation and density effects. The specific basis of comparison was: (i) phyllochron and the coefficient relating node number on the main stem and leaf area; (ii) effect of sowing density on these parameters. A side objective was to compare the generation of these coefficients in the field and in small pots.

2. Material and methods

2.1. Plant material

One pot experiment and four field experiments were conducted. The pot experiment (Exp. 1) was carried out at the end of the rainy season (October 2011 to January 2012, Fig. 1a) at the ICRISAT Sahelian Centre in (Sadoré, Niger, 45 km south of Niamey city, 13°N, 2°E). Three field experiments were also conducted at this location. Exp. 2 was done during the summer season (February to May 2012, Fig. 1b). Exp 3, was performed during and after the end of the rainy season 2012 (September to December, Fig. 1.c). Exp 4 was done during the rainy season 2014 (June to September, Fig. 1d). In addition, a field experiment (Exp 5) was done during the rainy season 2014 (August-December 2014 Fig. 1e) at the ICRISAT headquarter (Patancheru, India). The same ten peanut genotypes (55–437, ICGV 00350, ICG 12697, FLEUR 11, ICG 4750, TMV2, JL24, ICGV 91114, ICG 3584, ICG 1834), all Spanish botanical types, were included in Exp.1 and Exp.2. These genotypes were selected from the ICRISAT reference collection because of indications of contrasting differences in leaf area development under field tests in India and Niger.