Ontogenetic changes in growth and net photosynthetic rate of two peanut (*Arachis hypogaea* L.) cultivars

V. RAVINDRA, P.C. NAUTIYAL and Y.C. JOSHI

National Research Centre for Groundnut, Post Bag No. 5, Junagadh, 362 001 Gujarat, India

Abstract

The ontogenetic changes in growth, and the diurnal changes in net photosynthetic rate (P_N) and stomatal conductance were studied in two peanut cultivars of different habit groups. Significant cultivar differences were noticed: the prostrate cv. M 13 was found superior to the erect cv. J 11 in all the parameters studied. Specific leaf mass and the rates of gross photosynthesis and respiration were higher in cv. M 13 than in cv. J 11. In vegetative phase, the maximum P_N was in cv. J 11, but in pod filling phase, it was in cv. M 13. The differences in growth and P_N of the cultivars were significant after the onset of reproductive sink. Therefore, the screening for higher P_N has to be made at the pod-filling phase, and between 09.00 and 10.00 of the day (at optimum temperature).

Key words: crop growth rate, gross photosynthesis, harvest index, pod filling phase, specific leaf mass, stomatal conductance, vegetative phase.

Introduction

Growth and developmental differences in peanut are a function of genotype, subspecies and the environment (Williams *et al.* 1975, Duncan *et al.* 1978). The subspecific variation in net photosynthetic rate (P_N), stomatal conductance (g_s; Bhagsari and Brown 1976, Pallas and Samish 1974) and their diurnal variations (Pallas 1973, 1982, Pallas *et al.* 1974, Nayyar *et al.* 1990) were established at the vegetative phase only. The onset of the reproductive sink and the associated changes in growth and P_N needs better understanding. Enhancement of P_N from the existing

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Abbreviations: A - assimilatory surface, leaf area; CGR - crop growth rate; E - transpiration rate; g_s - stomatal conductance; NAR - net assimilation rate; PF - pod filling phase; P_G - gross photosynthetic rate; P_N - net photosynthetic rate; R_D - respiration rate; RS I, RS II - rain seasons I and II; SLA - specific leaf area; SLM - specific leaf mass; T_a - air temperature; T_l - leaf temperature; VG - vegetative phase; W - total biomass.

gene pool has become imperative to increase productivity in peanut. The present study aims at understanding the influence of reproductive sink on growth and P_N in two peanut cultivars of contrasting growth habits and in identifying the growth phase and solar time at which screening can be made for higher P_N.

Materials and methods

Field experiments were conducted in two rainy seasons (June-October; RSI and RSII) for growth studies and for net photosynthetic rate (P_N) and stomatal conductance (g_s) in summer (January-June) season in two peanut (*Arachis hypogaea* L.) cultivars, J 11 (ssp. *fastigiata*, var. *vulgaris*) of erect growth and sequential flowering, and M 13 (ssp. *hypogaea*, var. *hypogaea*) of prostrate growth and alternate branching/flowering habits, following recommended agronomic crop management practices.

Growth: The experiment was laid out in a completely randomized block design with five replicates in 5 × 5 m plots at 45 × 10 cm spacing. The crop was rainfed and irrigations to field capacity were given as required. Three adjacent plants from each plot were sampled at 10-d intervals between 20 and 90 d from sowing, separated into different plant parts and dried at 80 °C to a constant mass. Leaf area was estimated from area to dry mass ratio based on a sub-sample, whose area was measured on leaf area meter (*LI-3000, Li-Cor* Lincoln, NE, USA). The growth attributes - net assimilation rate (NAR), specific leaf mass (SLM), specific leaf area (SLA), and crop growth rate (CGR) were computed following Hunt (1982). The mean gross photosynthetic (P_G) and respiration (R_D) rates were computed for the growth interval between 20 and 90 d from sowing according to Ondok (1970) assuming that the P_G is proportional to the assimilatory surface, and the losses caused by respiration are proportional to the total biomass. The relation of increment in total biomass to the assimilatory surface and total biomass was expressed as,

$$dW = P_G\, A\, dt - R_D\, W dt,$$

where, W is the total biomass, A the assimilatory surface (usually leaf area), P_G is gross photosynthetic rate [g m^{-2} d^{-1}] and R_D the respiration rate [g g^{-1} d^{-1}].

These parameters were determined from regression equations and the coefficients P_G and R_D represent the average values for a defined growth interval.

Photosynthesis and conductance: The results of the growth studies, prompted us to study P_N and g_s, at vegetative (VG) and pod filling (PF) phases and were superimposed on the growth data to derive conclusions. In the summer season the diurnal changes in P_N and g_S were studied between 07.00 and 18.00 at VG and PF. The cultivars were grown in plots of 5 × 3 m, at 45 × 10 cm spacing and irrigated to field capacity regularly. Data on P_N, g_s, temperatures of leaf (T_l) and air (T_a), and transpiration rate (E), were recorded on top, young, fully expanded leaflets in four plants with *LI-6200* (*Li-Cor*, Lincoln, NE, USA) portable photosynthesis system.

Results

Growth: The growth rates of both cultivars were higher in all respects in RS I than in RS II with similar trends of dry mass accumulation and leaf area development during

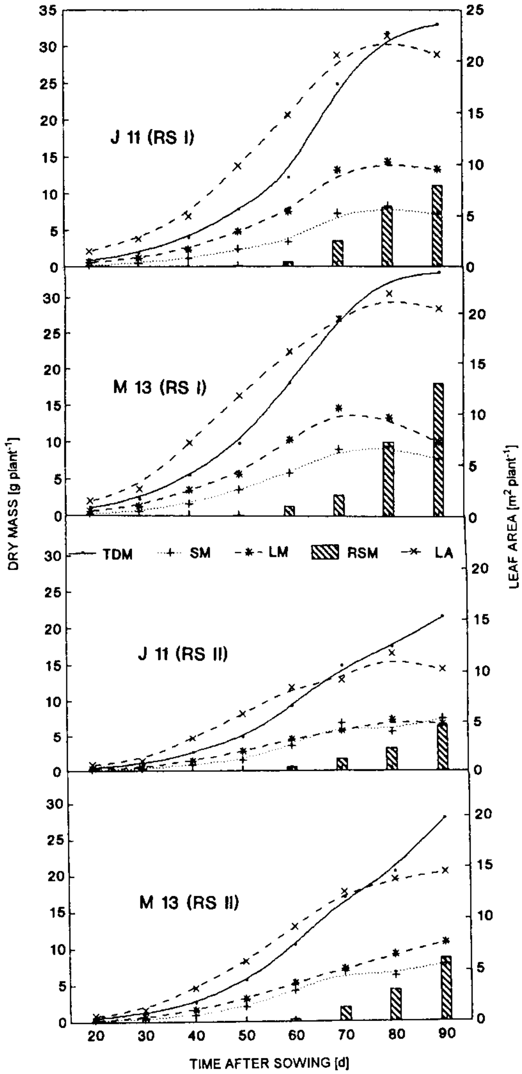

Fig. 1. Trends in dry mass accumulation and leaf area development in two peanut cultivars during ontogeny (TDM - total dry mass, SM - stem mass, LM - leaf mass, RSM - reproductive sink mass, LA - leaf area).

the ontogeny. However, cv. M 13 had higher growth rates than cv. J 11 and its reproductive sink size increased from 60 d after sowing (Fig. 1). The cv. J 11 maintained higher SLA while cv. M 13 SLM. The CGR was maximum at 60 d from

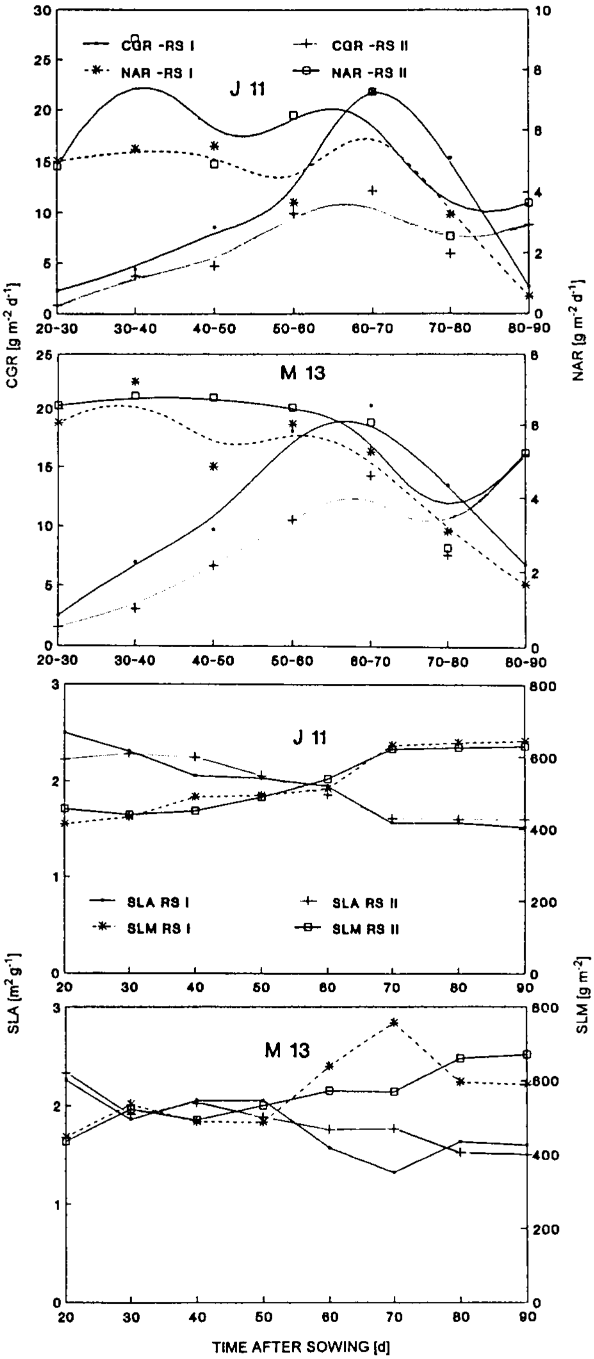

Fig. 2. Changes in crop growth rate (CGR), net assimilation rate (NAR), specific leaf area (SLA) and specific leaf mass (SLM) in two peanut cultivars during ontogeny.

sowing but NAR had peaks at VG and between 50 and 60 d after sowing and increased towards maturity (Fig. 2). The P_G and R_D were higher in cv. M 13 in both the rainy seasons (Table 1). The total dry mass, pod number and dry mass, 100 kernel mass and harvest index (HI) at maturity were higher in cv. M 13 than in cv. J 11 (Fig. 3).

Table 1. Mean rates of gross photosynthesis (P_G) and respiration (R_D) during the growth period (20 to 90 d after sowing).

	RS I		RS II	
	cv. J 11	cv. M 13	cv. J 11	cv. M 13
P_G [g m^{-2} d^{-1}]	7.31	9.9	8.88	9.91
R_D [g g^{-1} d^{-1}]	-0.030	-0.046	-0.030	-0.036

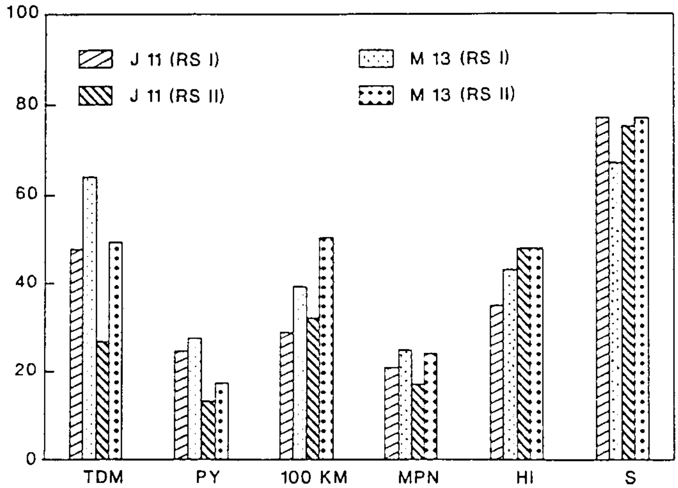

Fig. 3. Total dry mass (TDM) [g plant^{-1}], pod yield (PY) [g plant^{-1}], 100 kernel mass (100KM) [g], number of mature pods (MPN), harvest index (HI) [%] and shelling (S) [%] at maturity in two peanut cultivars.

P_N and g_s: The mean P_N, g_s, E, and T_l - T_a were significantly higher in cv. M 13 than in cv. J 11 at both the phases (Fig. 4). The P_N maximum in cv. J 11 was at VG but at PF in cv. M 13. The mean P_N in cv. M 13 at PF was about 1.5 times higher than that observed at VG with concurrent changes in g_s. The increase in g_s at PF resulted in higher E than P_N from 14.00. The P_N was maximum when T_l was between 30 and 35 °C. The difference T_l - T_a was higher at VG in cv. M 13 but at PF in cv. J 11. The P_N, E and g_s were higher when T_l - T_a was lower (Fig. 4).

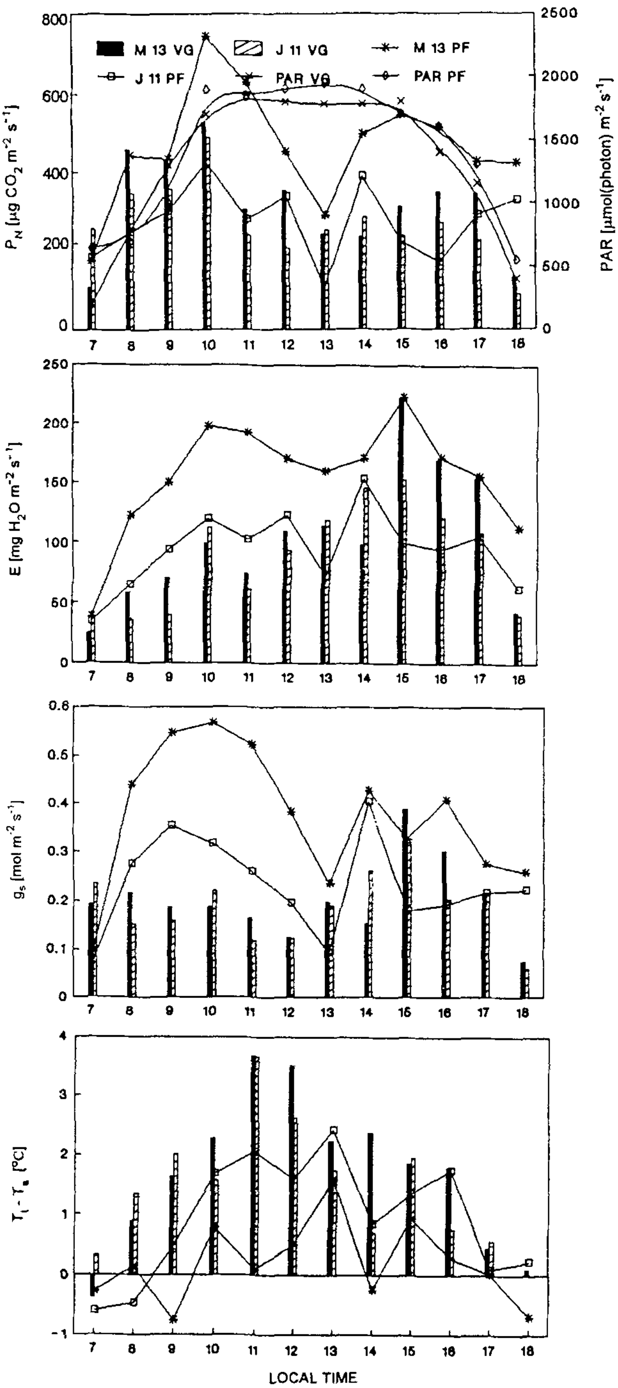

Fig. 4. Diurnal changes in P_N, g_S, E, and T_l - T_a in two peanut cultivars at vegetative and pod filling phases. PAR = photosynthetically active radiation.

The correlation between P_N and E was positive (r = 0.61) but its significance varied with the growth phase and cultivar. The correlation coefficients were 0.22 at VG and 0.84 at PF. They were 0.25 and 0.78 in cv. M 13 and 0.09 and 0.63 in cv. J 11 at VG and PF, respectively. The coefficients between P_N and g_s were 0.73 in cv. M 13 and 0.56 in cv. J 11.

Discussion

Genotypic differences in growth and development of peanut have already been reported (Williams *et al.* 1975, Duncan *et al.* 1978). The better growth, development and productivity of the two cultivars in RS I were due to the prevailing optimum temperatures (30 °C) and more sunny days during ontogeny. Peanut has an optima around 30 °C for various physiological processes at different growth phases (Williams *et al.* 1978, Cox 1979). The higher P_G of cv. M 13 was due to maintenance of a lower SLA and higher SLM. Since, these traits are stable, they can be used as selection criteria in the peanut improvement programs to enhance photosynthesis. The higher CGR, NAR, SLM, P_N and a decline in SLA at PF indicate the demand for photosynthates by the reproductive sinks as also observed by Williams and Allison (1978). Our observations also confirm Duncan *et al.* (1978) that the *virginia* types maintain a higher mean CGR.

The reproductive sink size and its relative strength appear to have an innate bearing on P_N during PF and consequently the pod yield. Duncan *et al.* (1978), observed that partitioning of photosynthates to pods as the most influential physiological factor in yield determination, besides pod number and duration of pod filling. For such reasons, cv. M 13, which is of longer duration, yielded more than cv. J 11.

The cultivar differences in growth and P_N at PF, were due to their growth habit and the associated morpho-physiological changes. Therefore, the differential sink size and demand are contributing to variation in the P_N. The higher P_N during mid-day at VG in cv. M 13 than that in cv. J 11 at the same g_s as that of cv. J 11 might be due to a more efficient CO_2 fixation system at enzyme level. The genotypic variations in P_N of peanut are well established (Bhagsari and Brown 1976, Bravdo and Pallas 1982). The genotypes of ssp. *hypogaea* photosynthesize better than those of ssp. *fastigiata* (Pallas and Samish 1974).

It is obvious that screening for P_N should be done at PF as the relative size and strengths of the reproductive sink would have set in by then to tap the potential genotypic differences. The lesser T_l and T_a differences and the significant positive correlations between P_N, E and g_s in the cultivars only at PF also indicate the same. Besides, observations on P_N should be made between 09.00 and 10.00 as T_l and T_a would be around optimum for the expression of potential P_N. Since P_N is heritable (Branch and Pallas 1984), selective utilization of the genotypes from the ssp. *hypogaea* in peanut improvement programs, would go a long way in the enhancement of P_N and consequently its productivity.

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