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CARBON TRANSLOCATION ACCOUNTING FOR YIELD VARIATION IN PEANUT (*ARACHIS HYPOGAEA* L.)

K. VNOD PRABHU[1] and V. ARUNACHALAM
Division of Genetics, Indian Agricultural Research Institute, New Delhi 110 012. (India)

ABSTRACT

Nine lines of peanut (*Arachis hypogaea* L.) including four high yielders, one non-nodulating line and its progenitor parents, one high nitrogen fixer and a national check, were studied *in situ* for 14c translocation to various plant's parts- leaves,stem, root nodule, shell and kernel - at peg development and harvest stages. Of the 68% of observed yield variation accounted for by the carbon translocation to roots, nodules, shells and kernels at harvest, 65% was accounted by the former two traits alone. The relative increase in translocation to roots and nodules at harvest over peg development stage directly influenced pod yields. This was substantiated by the nature and magnitude of correlations between pod yield (PY) and % 14c at peg development (PD) and harvest (HS) stages. There was no correlation between PY and % 14c in (root+nodule) at PD; but that correlation at HS was positive and significant. The observed differences in 14c partitioning between the high and low yielders suggest partitioning of carbon to reproductive parts as an additional economic selection criterion for improving productivity in peanuts.
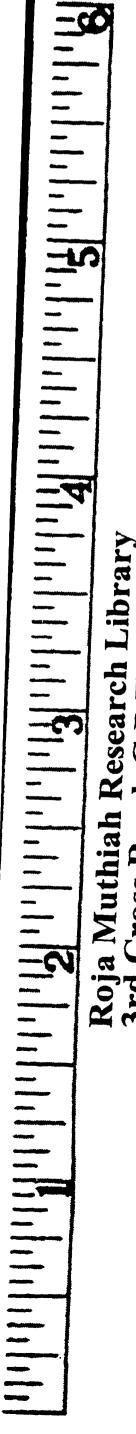
Key words   Peanut; Yield potential; Selection; Assimilate partitioning; Carbon translocation.

INTRODUCTION

Among the factors determining pod yield in peanut, partitioning of daily assimilates to the growing fruit is of crucial importance. This inference was arrived at from a physiological analysis of yield differences of popular varieties released in the U.S.A. in the distant and recent past (Duncan *et al.*, 1978). While Dixie runner, one of the earliest varieties with an yield potential of 2.4 t/ha had a partioning factor of 41%, Early Bunch, a variety released in the recent past with an yield potential of 5.4 t/ha had a very high partitioning factor of 99%. Even under conditions limiting net photosynthetic rate, it has been found possible to increase inter-organ partitioning of dry matter from unusable vegetative parts to commercially useful sinks (Gifford *et al.*, 1984). Experimental evidence was wide to support this view (Graham, 1978; Carlson and Brun, 1984; Crafts-Bradner *et al.*, 1984). It will then be feasible to use translocation of assimilates to growing fruit as a selection criterion to improve productivity in peanuts.

At the Indian Agricultural Research Institute, a number of high yielding peanut lines has been derived in the research programme of a national project on peanuts. Four of those lines and a few genetically diverse lines differing in yield were used as the test material to ascertain the extent to which carbon translocation could account for the observed yield differences and wheather it could be a useful selection criterion. The results are reported here.

MATERIALS AND METHODS

Nine lines of peanut consisting of four developed in a national project (NFG 7, NFG D, NFP 140, 1441-A-1), a non-nodulating line, Non-nod and its progenitor parents, Nc 17 and PI 259747, a national check, Robut 33-1 and a high nitrogen fixing accession from North Carolina, NC Ac 2821 were grown in a randomised block design with three replications. The crop received a basal dressing of 50 kg P_2O_5 and 30kg N (as the available N in the soil was very low at 129 kg/ha) as per the national recommendations. At pegging stage, 250 kg gypsum (Ca So_4) was added. The crop was grown after the onset of monsoon. under recommended cultural practices. The lines were sown in single row plots of 5m length on ridges spaced 60cm and plants within a ridge spaced 10cm apart.

All the lines initiated flowering by 40 days after sowing (DAS). Pegs started developing 90 DAS and the crop reached harvest stage around 120 DAS. The peg development (90 DAS; PD) and harvest (120 DAS; HS) stages were used for measuring carbon translocation to plant parts.

In situ 14_c isotope feeding was employed to measure translocation. The isotope was fed on two plants per plot in the field (which was irrigated two days before sampling) after caging the plants in special polythene chambers measuring 30cm× 30cm.× 30cm. Isotope solution in the form of sodium carbonate (28. 25m ci/m mole) was diluted to give 30μ ci/ml. 200mg non-radioactive sodium carbonate and 4ml distilled water were added 1ml isotope solution. $^{14}CO_2$ was released by mixing 8ml of 70% perchloric acid. The whole process had earlier been standardised by the radiotracer unit of the Department of Agricultural Chemistry, Andhra Pradesh Agricultural University, Hyderabad, India.

Each sample was incubated for 40 minutes. 24 hours after isotope feeding, the plants were pulled out and separated into leaves (LF), stem (SM), roots (RT), nodules (ND), shell (SH) and kernel (KL). The samples were dried in a hot air oven. The dried plant parts were separately ground fine and one g dry samples were exposed under a Geiger-Muller Counter (GCS 13) for 200 seconds at 1410 working volts.

The distribution of ^{14}C was estimated taking into account the dry weight of plant parts. For example, Z_i, the % ^{14}C in plant part i was calculated as:

$$Z_i = \frac{W_i X_i}{\sum_{i=1}^{6} W_i X_i} \times 100$$

where w_i was the dry weight and x_i the isotope count of plant part i, i=1,6. i=1 refers to LF, 2 to SM, 3 to RT, 4 to ND, 5 to SH and 6 to KL.

Dry pod yields of the sampled plants were also noted.

RESULTS AND DISCUSSION

There was considerable variation among the 9 lines for dry weight and carbon translocation to plant parts as reflected in their mean values (Table 1). The lines, NFG 7, NFP D, 1441-A-1, Robut 33-1 and NC Ac 2821 gave pod yields per plant above the experimental mean (30.4 g plant^{-1}). In general about 75% of 14_C was translocated to leaf and stem with individual variation among lines. More than 80% of 14_C were found in leaf and stem in the lines NC 17, Non-nod and NFP 140. High % 14_C in the plant organs, root, nodule, shell and kernel, was observed in NFG 7 (31.3%) and Robut 33-1 (25.4%).

TABLE 1   Per cent dry weight (D) and 14c (T) in different plant parts at harvest in peanut.

Line	LF + ST		RT + ND		SH + KL		Pod yield (g/plant)
	D	T	D	T	D	T	
NC Ac 2821	50.4	77.2	2.5	4.6	47.1	18.2	31.9
NFG 7	51.2	68.7	2.4	6.0	46.4	25.3	45.3
NFP D	51.1	76.5	2.4	4.7	46.5	18.8	36.2
NFP 140	53.2	80.5	3.0	3.2	43.8	16.3	24.0
1441-A-1	53.5	67.2	3.0	3.8	43.5	21.0	36.1
NC 17	58.4	83.8	3.1	4.1	38.5	12.1	21.4
PI 259747	60.1	75.3	4.3	2.8	35.6	21.9	19.9
Non-nod	67.9	80.9	3.6	2.1	28.5	17.0	9.5
Robut 33-1	50.3	74.6	2.5	4.3	47.2	21.1	49.2
Mean	55.1	76.1	3.0	4.0	41.9	19.1	30.4
SE ±	5.94	5.48	0.64	1.15	6.46	3.81	8.04

Dry weights were distributed among above ground (leaf+stem) and underground (root+nodule+shell+kernel) organs almost equally (Table 1). Non-nod provided an exception where the dry weight of leaf and stem was about double that of the rest of the organs.

High yielding lines like NFG 7 and Robut 33-1 partitioned relatively high carbon to root, nodule, shell and kernel while the opposite was true of low yielders like NC 17 and Non-nod. In some lines such a direct association was not apparent. For example, carbon patritioned to underground parts was 24.8% for 1441-A-1 with an yield of 36.1 g plant^{-1}. This difference for PI 259747 with an yield of 19.9 g plant^{-1}. This difference was complemented by a higher dry matter accumulation in 1441-A-1 in pod (SH+KL), double that of PI 259747 at harvest. As inferred in grain legumes

like chickpea and pigeonpea, efficient mobilisation of carbon and nitrogen from stem and leaves and high photosynthetic and N-fixing rates during seed filling would also be the other important factors for explaining differences in productivity (Singh, 1990). Maximum C and N fixation occurred during flowering and early fruiting phases in chickpea while about half of the net photosynthate and N were fixed in the vegetative period itself in pigeonpea allowing for better remobilisation to pods at periods of seed fill explaining its comparatively higher yields.

The association between pod yield and 14_C and in various plant parts varied between peg development and harvest stages (Table 2). While none of the correlation coefficients between pod yield and 14_C in (leaf+stem), (root+nodule) or (shell+ kernel) was significant at peg development stage, the former two was significant at harvest. In particular, there was a positive and significant correlation between 14_C in (root+nodule) and pod yield at harvest.

TABLE 2. Correlation coefficients (r) between % 14c in various plant parts and pod yield at peg development (PD) and harvest (HS) stages in peanut.

r	PD	HS
PY, C in (LF + ST)	-0.55	-0.67*
PY, C in (RT + ND)	0	0.81*
PY, C in (SH + KL)	0.52	0.60

*Significant at P=0.05

Such an association was lacking between dry weight of plant parts and 14_C in them at both stages (Table 3). The only exception was a negative correlation between dry weight and 14_C of (leaf+stem) at harvest. There was thus no premise *a priori* on which dry weight of plant parts could substitue 14_C in them as selection criteria.

TABLE 3. Correlation coefficients (r) between dry weights and % 14c in various plant parts at peg development (PD) and harvest (HS) stages in peanut.

r	PD	HS
LF + ST	-0.63	-0.75*
RT + ND	0	0.48
SH + KL	0.64	0.47

*Significant at P=0.05

The relative efficiency of several linear regression equations in accounting for the observed variation in pod yield was then compared. Only two equations, numbered 1 and 3 (Table 4), could account, with a single independent variable, for more than

50% of variation in pod yield. Of these two, the linear regression equation between pod yield and % 14_C in (root+nodule) at harvest was the best accounting for 65.5% of variation in pod yield. When 14_C in (shoot+kernel) was also included the coefficient of determination could rise only to 68.4% not justifying their inclusion despite the extra cost and time in measuring them. But the relative increase in 14_C in (root+nodule) at harvest over peg development stage was found to be an important factor in determining pod yield (R^2=54%, Table 4).

TABLE 4. Regression equations of pod yield (Y) on percent 14c (x) partitioned to roots and nodules in peanut.

	Regression equation	R^2
1	Y = -5.2 + 8.98* x_1	65.5
2	Y = -38.6 + 1.61* x_2	68.4
3	Y = 21.2 + 0.17* x_3	54.0

x_1 : 14c in (root + nodule) at harvest;

x_2 : 14c in (root + nodule + shell + kernel) at harvest;

x_3 : Relative increase in 14c in (root+nodule) at harvest over peg development stage.

R^2 : Coefficient of determination

The results led to two major inferences:

a. Pod yield was a function of partitioned carbon to roots and nodules.

b. The increase in partitioning to roots and nodules from peg development to harvest stages had a substantial influence on realised pod yields.

Evidence to support partitioning of assimilates to reproductive parts as a selection criterion is abundant in published literature. Its use in constructing productive legume plant types had earlier been recognised (Graham, 1978). Where efforts were unsuccessful at increasing the rate of photosynthesis, inter-organ partitioning of photosynthates was used as a successful method to realise commercial sinks (Gifford et al., 1984). Higher rate of photosynthate translocation to developing pods during peak filling period (corresponding to pod development stage of this study) resulted in higher yields of groundnut mutants compared to other derived genotypes (Lodha et al., 1983). In general, at the pod filling stage, a majority of 14_C is required to be translocated to pods as plant parts compete for carbon among themselves for assimilation into specific sinks (Russell and Johnson, 1975). When accumulated carbohydrates in the stem were not remobilised for seed development, poor yield resulted in Phaseolus (Adams et al., 1978). Selection of genotypes with more specific sink demands (where leaves translocated most photosynthates to pods) has been practised in soybean (Carlson et al., 1984) and cowpea (Pate et al., 1984). Published evidence suggests the need to select genotypes with

profuse pod formation to generate more sink demand as was done in soybean (Carlson *et al.*, 1984) or that the sink demand itself did not exhaust the available source resulting in the retention of photosynthates in the leaves at late pod filling period (Egli *et al.*, 1980) which limits realisation of the full genotypic potential.

Selection that can be operated before digging of pods saves a lot of time and labour in peanut research. In an earlier study (Prabhu *et al.*, 1990) the utility of leaf area and total nitrogen % measured 30 days after flowering in selecting productive genotypes was highlighted. This investigation adds one more vital selection parameter namely, the rate and extent of carbon translocation to reproductive sinks around harvest.

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