J. Oilseeds Res. 11(2) 1994 : 259-268
ISSN 0970-2776

PROSPECTS FOR UTILIZATION OF GENOTYPIC VARIABILITY FOR YIELD IMPROVEMENT IN GROUNDNUT*

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ABSTRACT

During the past decade, significant progress has been made in identifying resistance sources and developing groundnut cultivars with resistantce to major biotic constraints. However, very little progress has been made in identification and exploitation of genetic traits contributing improvement of yield potential and adaptation.

An understanding of physiological factors influencing yield components and the development of simple screening techniques to select for traits contributing to yield is central to the development of appropriate genotypes. Recent research on groundnut physiology at ICRISAT Asia center has indicated substantial variation among genotypes for desirable traits like water-use efficiency (WUE), partitioning of dry matter to pods (p) and efficient root systems etc. However, measurement of these traits is complex and laborious. Significant correlations amongst WUE, carbon isotope discrimination in leaf and specific leaf area (SLA), suggested that SLA can be used as a surrogate for carbon isotope discrimination to identify genotypes with high WUE.

The adaptation of improved genotypes to varied environments is one of the major problems in groundnut improvement program. Although significant genotype x environment interactions have been noted, there is little emphasis on understanding and exploiting variability for specific adaptation. There seems to be scope for yield improvement in groundnut by selecting for physiological attribute(s) contributing to yield advantage in a given environment and combining them to enable further identification of genotypes with desirable combinations of traits. Scope also exists to enhance productivity of groundnut by sacrificing wider adaptation and instead developing varieties with specific traits to match certain special agro-climatic requirements.

Keywords: Groundnut; Yield improvement; Physiological traits; Adaptation.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important oilseed and cash crop in India, where it is grown over 7.4 million hectares, predominantly under rainfed conditions. Although India is the world's largest producer (6.4 million tonnes per year), the national average productivity was 0.7-0.9 t ha^{-1} during the past decade, compared to the world's average of about 1.1 t ha^{-1} (Fletcher *et al.*, 1992). The gap between Indian and the world productivity has been consistent

* Invited paper presented at the National Seminar on "Oilseeds Research and Development in India: Status and Strategies" 2-5 Aug. 1993, Hyderabad. Indian Society of Oilseeds Research, Hyderabad.

Received for publication on December 23, 1994.

over last decade. A marginal increase in groundnut production during the past 5 years (9%) is attributable to 12% increase in area and 6% increase in productivity (AICORPO, 1993). The on-farm average yields in India (ca. 0.8 t ha^{-1}) are much lower than in the developed countries (2.5 t ha^{-1}). There is an urgent need to enhance yields, both in terms of quantity and quality, if India is to compete in international groundnut trade.

In Zimbabwe, on-farm yields of about 9.6 t ha^{-1} was reported (Hilderbrand, 1980). Sun Yanhas and Wang Caibin (1990), reported pod yields of 11.2 t ha^{-1} in a 0.1 ha plot and 9.6 t ha^{-1} from 14 ha plot in Shandong province in China. At ICRISAT Asia Center(IAC), yields up to 7 t ha^{-1} have been achieved on small plots and up to 5 t ha^{-1} larger plots. On-farm trials conducted under an ICAR-ICRISAT collaborative project during 1988-90 have shown that yields of groundnut up to 5 t ha^{-1} could be obtained on large plots (0.2 ha) when improved technologies were adopted. These studies also showed that improved genotypes contributed 25-28% and improved management contributed 30-32% to the observed increase in yield. However, appropriate combination of improved genotype and crop management resulted in a synergistic improvement in yield ranging from 50 to 150% (Nene, 1993). Obviously, the logical approach to increase yield in groundnut calls for an appropriate combination of crop improvement and management.

The dry matter yield of groundnut crop at final harvest can be described as:

$$Y = CGR \times D \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where CGR is the crop growth rate (defined as dry matter produced per unit land area per unit time, usually expressed as g m^{-2} day^{-1}) and D is the crop duration in days. The pod yield at the final harvest can be described as:

$$Y_P = CGR \times D \times p \ldots\ldots\ldots\ldots (2)$$

Where p is the proportion of the daily assimilates partitioned into pods during the pod filling phase.

If the crop's duration is assumed to be fixed for a given location or cropping system, then CGR and p are the major determinants of the final yield. Both CGR and p are influenced by both genetic and environmental factors. In this paper, we consider some major crop attributes that determine productivity in groundnut, and examine scope for crop improvement by exploiting genetic variability in these atrtributes.

Radiation interception and Radiation-use efficiency

There is considerable evidence that all crops (including groundnut) accumulate dry matter at a rate proportional to the amount of radiation that the foliage intercepts during the growing period (Mathews *et al.*, 1988 b, Azam-Ali *et al.*, 1989). Any factor that reduces radiation interception below the optimum limit can reduce yield by limiting the photosynthetic area per unit ground area. In groundnut, complete ground cover resulting in >95% radiation interception by foliage is achieved at a leaf area index (LAI) of approximately 3. Once this has occurred, the CGR depends mainly on other limiting factors such as availability of water and crop growth duration. The CGR response to increased leaf area above LAI of 3 is generally small, although there are some reports of 20% more growth at a LAI 6 than at LAI of 3 (Williams, 1979).

Table 1. Yields and RUE of TMV 2 and narrow mutant of TMV 2 (TMV2-NLM) grown under irrigated and water deficit conditions at ICRISAT center.

Genotype	1989-90 postrainy			1990 rainy					
	(Irrigated)			(Irrigated)			Mid-season drought		
	Adj Bio ($t\ ha^{-1}$)	Pwt $t\ ha^{-1}$)	RUE ($g\ MJ^{-1}$)	Adj Bio ($t\ ha^{-1}$)	Pwt ($t\ ha^{-1}$)	RUE ($g\ MJ^{-1}$)	Adj Bio ($t\ ha^{-1}$)	Pwt ($t\ ha^{-1}$)	RUE ($g\ MJ^{-1}$)
TMV2	11.1	3.3	0.95	6.14	1.3	NA	5.18	0.78	0.59
TMV2-NLM	12.2	3.9	1.16	7.50	1.2	NA	7.20	0.89	0.75
SE	±0 .76	±0.31	±0.06	±0.29	±0.04	-	±0.29	±0.04	±0.08
C.V.	13.2	25.2	18.1	4.8	5.1	-	4.8	5.1	21.1

Adj Bio = Adjusted total biomass; Pwt = Pod weight; RUE = Radiation use efficiency

Experiments conducted at IAC and elsewhere indicate genotypic variability in groundnut for radiation-use efficiency (RUE), defined as the dry matter produced per unit amount of radiation intercepted (Mathews *et al.*, 1988b, Nageswara Rao, 1992). There seems to be limited scope for manipulating RUE by altering canopy structure and geometry. In a field study conducted at IAC, we examined the influence of canopy structure on productivity of groundnut using selected mutants with varied leaf size and shape. Results showed that TMV 2-NLM (a mutant of TMV 2 which has narrow leaves but greater number of leaves), produced more total dry matter than TMV 2 (Table 1). One of the main physiological factors responsible for greater dry matter production in TMV 2-NLM was the increased RUE in the former. The narrow leaf morphology in TMV 2-NLM reduced mutual shading by leaves, thus allowing more radiation to penetrate into the canopy. It is possible, however that in addition to a modified canopy structure, TMV 2-NLM may have an altered genetic makeup for other yield attributes. Isogeneic lines are needed to accurately quantify the contribution of individual traits to yield. The role of crop canopy structure in groundnut productivity needs further investigation.

Water use and Water-use efficiency

Many studies have demonstrated a significant positive relationship between dry matter production and the amount of water transpired during the growing period (Ong *et al.,* 1987; Azam-Ali *et al.,* 1989) (Fig.1). This implies that any genetic attribute and/or management practice that enhances transpiration component in the total evapo-transpiration would increase dry matter production.

Recent studies revealed substantial genotypic variation among groundnut germplasm for water-use efficiency (WUE), defined as dry matter produced per unit amount of water transpired (Hubick *et al.*, 1986, Mathews *et al.,* 1988a, Wright *et al.*, 1988, Nageswara Rao *et al.,* 1993). While a higher WUE is potentially useful, WUE is not an easy trait to exploit in a breeding program because of practical difficulties involved in measurement of transpiration and total crop (shoot + root) mass in field experiments. A significant relationship between WUE ^{13}C : ^{12}C isotope

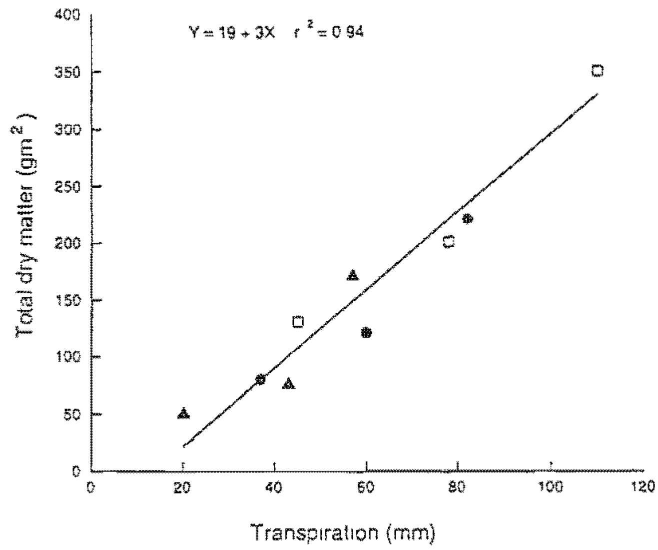

Fig. 1: Relationship between transpiration and total dry matter production in groundnuts grown at three plant spacings (35 x 10 cm ▲ ; 70 x 10 cm ● ; 120 x 10 cm □). Postrainy season 1981-82, ICRISAT Asia Center (from Azam-Ali *et al.* 1989)

discrimination during CO_2 assimilation in leaves has been demonstrated in a range of crops including groundnut (Farquhar and Richards, 1984; Hubick *et al.*, 1986, Wright *et al.*, 1988, Nageswara Rao *et al.*, 1993, Wright *et al.*, 1994). This suggests that carbon discrimination ratio is a potential selection tool to identify groundnut genotypes with high WUE (Fig 2). However, determination of the carbon isotope discrimination ratio requires expensive and sophisticated mass spectrometry facilities which are not easily available in developing countries.

In a recent study, a significant negative relationship was observed between WUE and specific leaf area (SLA) (Wright *et al.*, 1994, Fig 3) SLA, defined as leaf area per unit leaf dry wt (cm^2 g^{-1}), is an indicator of leaf thickness. Both environment and genotype can significantly influence carbon isotope discrimination ratio and SLA, but the G x E interaction for these parameters appears not to be significant (Nageswara Rao and Wright, 1994). This observation implies that SLA, which is a crude but easily measurable parameter, can be used as a rapid and inexpensive selection criterion for high WUE. Screening of groundnut germplasm for SLA indicated significant variability within and between taxonomic groups. It was interesting to note that the genotypes belonging to variety *hypogaea* (virginia bunch and runner), lower mean SLA(Fig 4a), suggesting a likelyhood of higher WUE. However, virginia bunch and virginia runner had lower partitioning ability than valencia and spanish types(Fig 4b). There is need to identify genotypes with high WUE and high partitioning for use in groundnut breeding programs.

Partitioning of dry matter to pods

Pod growth rate (PGR), defined as pod dry matter produced per unit land area per unit time, is an important component of CGR and

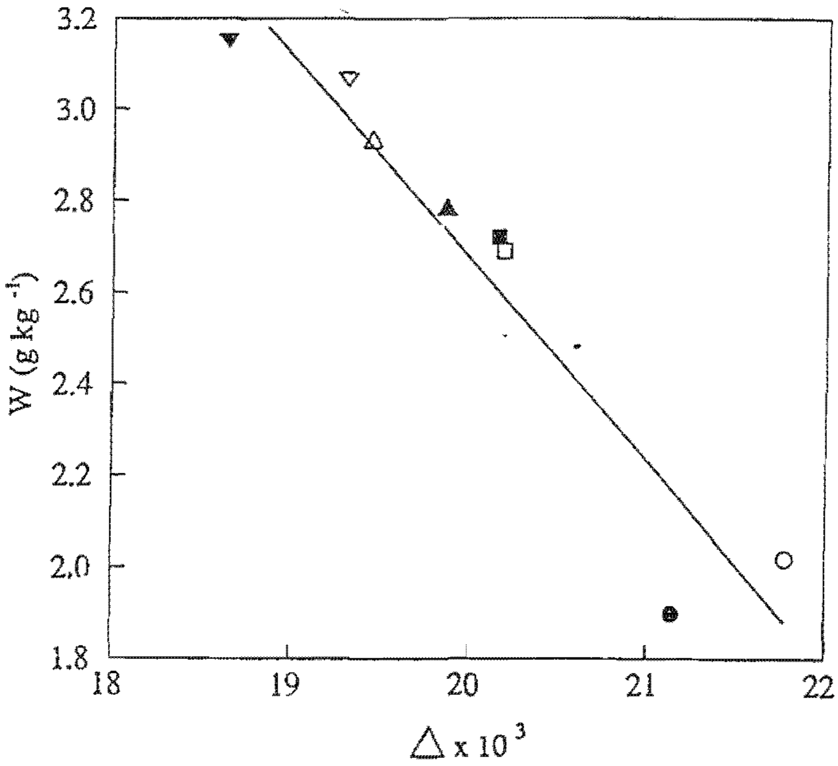

Fig. 2: Relationship between water-use efficiency and carbon isotope discrimination in 4 groundnut genotypes, Chico (○), McCubbin (□), Shulamit (△) and Tifton-8 (▽), grown under intermittent (closed symbols) and continuous (open symbols) drought treatment in 1990-91 season at Kingaroy, Australia (from Wright *et al.* 1994).

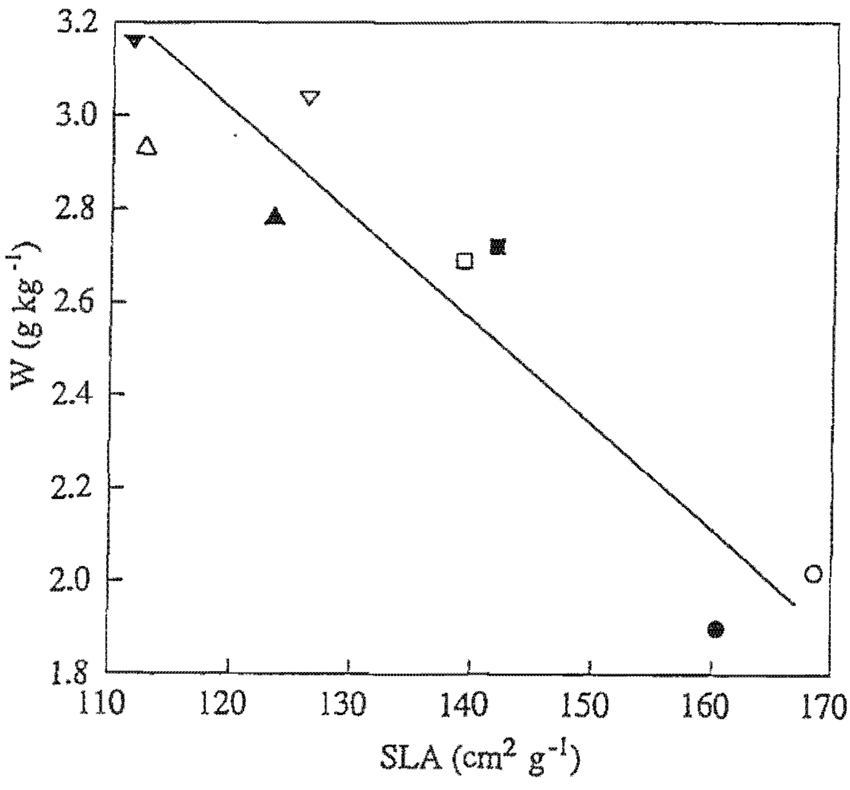

Fig. 3: Relationship between water-use efficiency and specific leaf area in 4 groundnut genotypes, Chico (○), McCubbin (□), Shulamit (△) and Tifton-8 (▽) grown under intermittent (closed symbols) and continuous (open symbols) drought treatments during 1990-91 season at Kingaroy, Australia (from Wright *et al.* 1994).

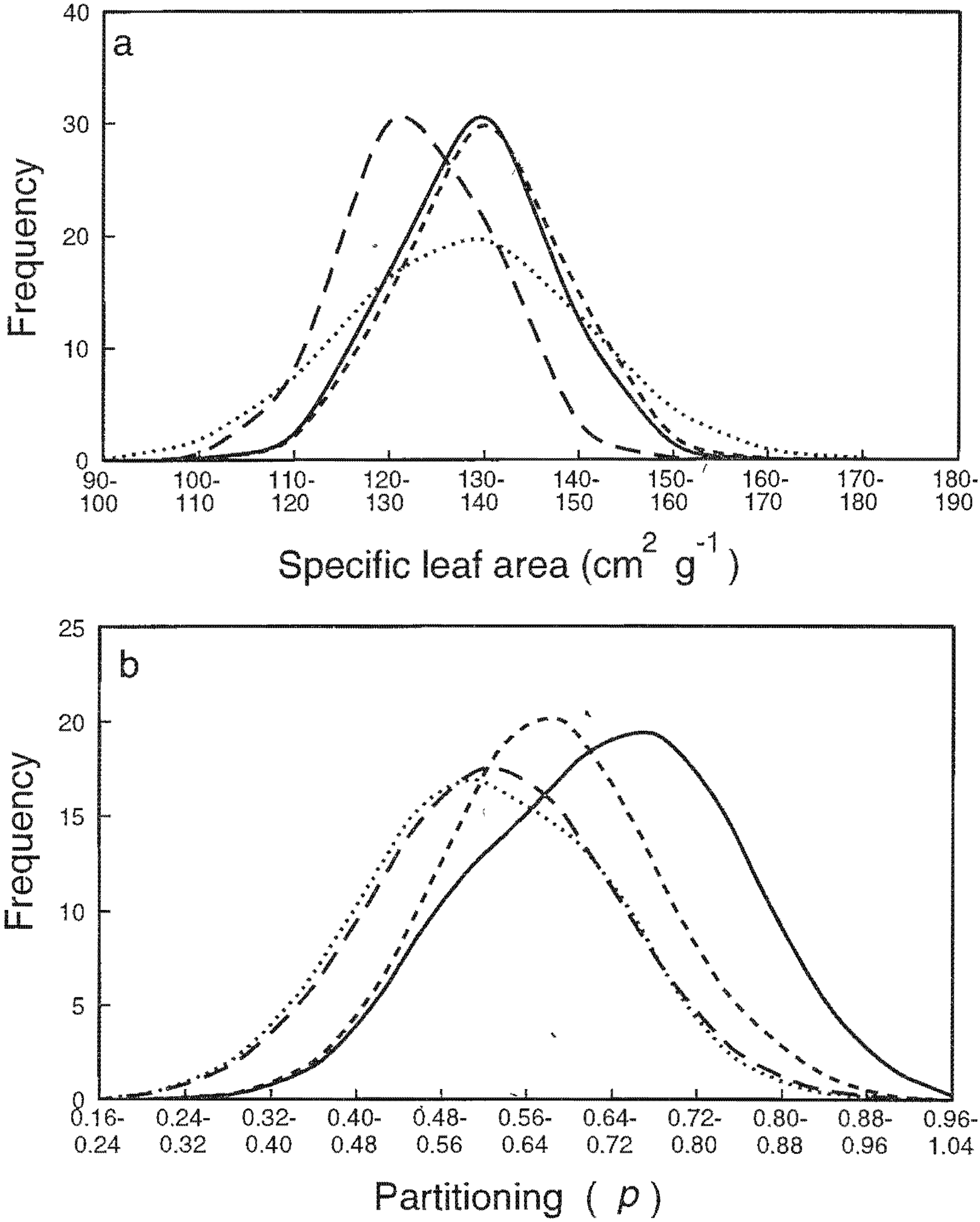

Fig. 4: Specific leaf area (SLA) (a) and partitioning, *P* (b) in 64 groundnut germplasm accessions of different botanical types. Postrainy season 1992, ICRISAT Asia Center (spanish - - -, valencia ——— , virginia bunch ...., virginia runner — —).

determinant of pod yield. In addition to equation (2), pod yield achieved at harvest can be described as:

$$Y_P = PGR \times D \quad \text{..................} (3)$$

Pod growth rate is dependent on both genotype and environment. Although there is considerable variation among genotypes for p (Fig. 4b), conventional methods of determining p are laborious and cumbersome, and are unsuitable when a large number of entries need to be evaluated for this trait. However, simple, non-destructive methods can be effectively used as preliminary screening tools to identify genotypes with efficient partitioning attributes (Williams and Saxena, 1991).

Adaptation to specific environments

Several biotic (diseases, insect pests, etc.) and abiotic factors (photoperiod, soil moisture, soil acidity, nutrient status, etc.) can influence pod growth resulting in significant effect of environment on yield.

Let us, for example, examine the adaptation of improved groundnut genotypes to two types of soils, Alfisols and Vertisols, which are the two major soil types on which groundnut is grown in india. Soil fertility problems, which are likely to be very diverse and location specific, can be overcome to some extent by the use of fertilizers and other amendments. However, inherent physical properties of soil also vary with type (El-Swaify and Caldwell, 1991) and are particularly important because of the subterranean fruiting habit of groundnut. From the crop adaptation point of view, it is important to determine whether high-yielding genotypes developed on one soil type are adapted to other soil types. Several trials conducted at IAC to examine genotype x soil type interaction suggested that groundnut growth and yield were superior in Alfisols than Vertisols (Nageswara Rao *et al.*, 1992). A detailed study of genotype x water deficit interaction conducted on the two soil types at IAC indicated that CGR was 40% greater on the Alfisol than on Vertisol, under adequately irrigated conditions. Although the occurrence of drought significantly affected crop growth on both soils, the effect of time of occurrence of drought on crop growth varied with the soil type. Drought during the pod-filling phase resulted in significant yield reduction on the Alfisols, while on the Vertisol, occurrence of drought during pod set phase appeared to be more detrimental to yield. Partitioning of dry matter to pods (p) was significantly lower on the Vertisol than on the Alfisol.

The CGR on the Alfisol was positively correlated ($r^2 = 0.77^{**}$, $P < 0.01$) with CGR on Vertisol, but there was no such relationship for p ($r^2 = 0.38$) between the two soil types. This suggests that high-yielding genotypes developed on Alfisols may maintain their relative rankimg for total dry matter on Vertisols, but not for pod yields (Fig. 5a and 5b). It appears that productivity of groundnut can be improved on Vertisols by developing varieties with specific adaptation.

Concluding remarks

Although genotypic variation exists for putative yield-determining traits like WUE, RUE and p , it is necessary to understand the interactions amongst the traits. At present very little is known about these interactions and their effect on yield.

We believe that sustainable yield improvement can be achieved if the attributes that contributes to yield advantage in a given

Fig 5a

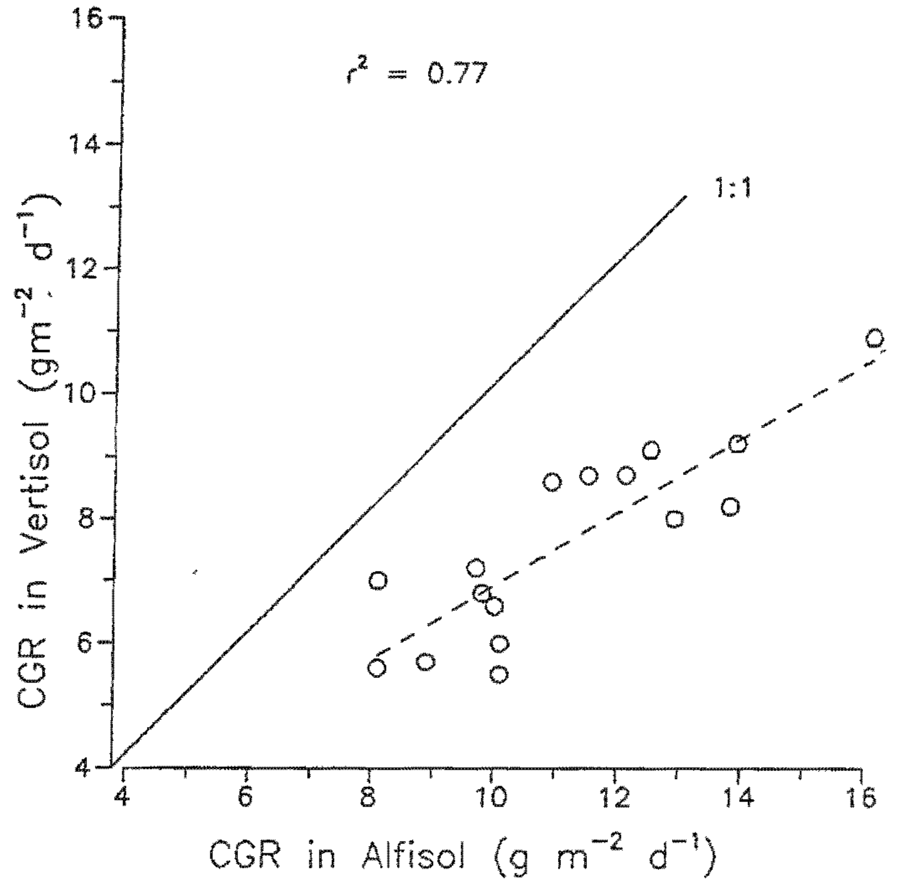

Fig 5b

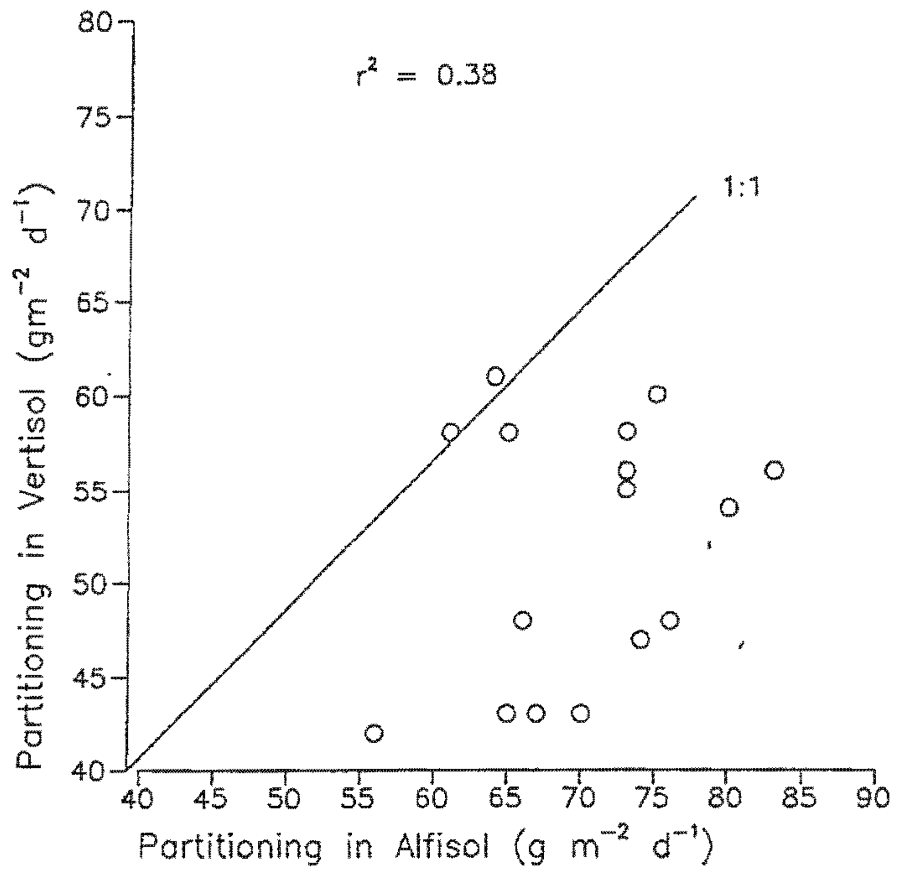

Fig. 5: Comparison of (a) crop growth rate (CGR) and (b) partitioning (*p*) of 4 groundnut genotypes grown on the Alfisol (a) and Vertisol (b) during postrainy season 1988-89, ICRISAT Asia Center.

environment are identified and used in breeding programs to enable identification of genotypes with desirable combinations of traits. Groundnut productivity can also be improved by sacrificing wider adaptation and developing varieties with specific adaptation to match local agroclimatic requirements.

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