Improving water use efficiency and drought tolerance in groundnut by trait based breeding programmes in India

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Abstract

Multi-location trials (MLT`s) were conducted to screen groundnut (*Arachis hypogaea* L.) germplasm for high water use efficiency (WUE). Specific leaf area (SLA) a surrogate of $^{13}C/^{12}C$ (Δ) was used to screen the germplasm for WUE. The multi-location data was analysed based on the model i.e. Pod yield = T x TE x HI, where T= transpiration, TE = transpiration efficiency, and HI = harvest index. The combined analysis of the multi-location trials demonstrated that high pod yield under deficit-water stress was associated with a combination of traits such as T, WUE, and HI, indicating these traits are not physiologically linked. A combined analysis of the MLT`s has indicated that G x E interactions for SLA/WUE traits is moderately high. Some genotypes, however; were stable over a range of environments. Physiological studies of the low and high SLA genotypes showed that low SLA types are capable of retaining more water (RWC) in the leaf under water-deficit situations than the high SLA genotypes. Genotypes found with high WUE are used in a trait based breeding programme as donor parents.

Media summary

Trials were conducted to screen peanut germplasm for high WUE in India. The high WUE genotypes identified based on the low SLA (thicker leaf) were used in the trait based breeding programme to improve WUE and overall drought tolerance in groundnut.

Key Words

Groundnut, water use efficiency, specific leaf area, transpiration, transpiration efficiency, and harvest index.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important oilseed as well as food legume grown commercially in about 8 million ha in India, mostly under the rain-dependent situations. Drought of various intensities and duration severely limits the productivity of groundnut. Though several agronomic interventions to conserve the soil moisture and enhance the water use efficiency (WUE) are advocated, tailoring groundnut varieties tolerant to drought and efficient in water use offers the best long term and cost effective solution to encounter the uncertainty of monsoon and shrinking availability of irrigation water in the country. So far the approach to breeding cultivars with superior yield performance under water limited conditions has remained empirical, *via* selection for yield under stress conditions. It is now believed that more rapid progress can be aided by a prior knowledge of the physiological basis of trait performance such as specific leaf area (SLA), ability of root system to capture water for transpiration (T) and partitioning efficiency (*p*) or harvest index (HI) under drought conditions. Therefore, work in India was initiated in collaboration with QDPI, Kingaroy under ACIAR support to identify the traits associated with WUE and drought tolerance, screen the germplasm for WUE and initiate trait based breeding programme for higher WUE and drought tolerance in groundnut. Now molecular markers associated with WUE and drought tolerance are being studied.

Methods

Sixty-three groundnut germplasm accessions were screened for WUE based on SLA as a surrogate for $^{13}C/^{12}C$ (Δ), TE and HI at five locations in India. In these trials, detailed plant growth analysis and SLA measurements were conducted in three treatments i.e. irrigated (IRR), rain-dependent (RD), and simulated mid-season stress in rainout shelter (ROS). Carbon discrimination ($^{13}C/^{12}C$) was analysed by mass spectroscopy. The high WUE lines were identified and a Principal Component Analysis (PCA) was performed on a multi-location data set (Wright, et al. 1996).. . To develop drought tolerant genotypes with higher WUE, donor parents were identified based on traits such as T (transpiration), TE (transpiration efficiency), and HI (harvest index). Some of the parents such as CSMG 84-1, ICGV 86031, and TAG 24 (lower SLA) were compared with high or medium SLA types Chico, ICG 4747, and Kadari 3, in two contrasting seasons i.e. post-rainy and rainy seasons. Drought tolerance was studied by measuring photosynthesis (P_N), stomatal conductance (g_s), and leaf relative water content (RWC), under progressive soil-moisture-deficit conditions in a pot culture experiment at Junagadh (Nautiyal et al. 2002). In the second phase of the project three common crosses ICGS 76 x CSMG 84-1, ICGS 44 x CSMG 84-1 and ICGV 86031 x TAG 24 were made at Junagadh, Jalgaon, Tirupati and ICRISAT, India. One cross per location GG 2 x ICGV 86031 (Junagadh), JL 220 x TAG 24 (Jalgaon) K 134 x TAG 24 (Tirupati) and ICGS 44 x ICGS 76 (ICRISAT) were also made. Segregating populations were selected based on trait as well as empirical methods, and the material selected advanced to further filial generations. In the trait method a selection index (with equal weighting for T, TE and HI) was applied, whereas in the empirical method plants were selected based on visual pod yield at the final harvest. At the F_5 generation each of the five breeding centers contributed 48 selections for multi location testing (MLT).

Results

The combined analysis of multi-location traits (MLTs`) demonstrated that high pod yield under water-deficit stress was associated with a combination of traits such as T, WUE, and HI, indicating that these traits are not physiologically linked. Physiological studies of the low and high SLA genotypes showed that low SLA (thick-leaf) types are able to retain more RWC under soil moisture-deficit conditions and thus maintaining the higher P_N compared to the higher SLA (thin-leaf) genotypes. Among the top 20 entries, about half were derived from empirical approach and half from trait based selection, indicated that breeders` approach (empirical) for selecting superior types was as good as the trait selection method (Table 1). Only the top 7 entries showed significantly higher kernel yields (30 to 40%) over the local check GG 2. The parental line JL 220 that ranked 7 for pod yield was as good as any other top performing genotype derived through hybridization. Among the top 20 genotypes, JL 220 showed high HI (0.32) and lowest TE (2.37 g/kg/ha) and moderate T (318 mm). Unlike pod yield, significant differences were observed for HI, TE and T. Paradoxically, the genotype TAG 24 showed highest kernel yield and lowest water loss due to T. The top 20 genotypes pooled over 14 environments are being evaluated further in the AICRP-Groundnut trials, to be utilized in future breeding programmes aimed at developing WUE in groundnut.

Table 1. Performance of some of the the groundnut genotypes developed for higher WUE in terms of pod yield (ton/ha), transpiration efficiency (TE, g/kg/ha), transpiration (T, g/ha) during the rainy season in Junagadh (long. 70.36?E, and lat. 21.31?N), India.

Genotype	Geno-ID	Parentage	Cross No.	Sel. type	Pod yield	HI	TE	T
167	ICR 20	TAG 24 x ICGV 86031	8	IRRI	2.42	0.34	2.54	304
187	ICR 10	ICGS 44 x ICGS 76	7	DRO	2.38	0.30	2.55	319
124	JUG 15	ICGS 76 x CSMG 84-1	1	IRRI	2.34	0.32	2.64	288

98	JAL 03	ICGS 76 x CSMG 84-1	1	DRO	2.33	0.31	2.61	313
69	JUG 28	ICGS 76 x CSMG 84-1	1	EMP	2.31	0.29	2.63	321
161	ICR 40	TAG 24 x ICGV 86031	8	EMP	2.30	0.26	2.55	375
132	ICR 11	ICGS 44 x ICGS 76	7	DRO	2.21	0.29	2.61	302

Conclusion

Water use efficiency in groundnut can be increased either by the conventional breeding or trait based selection, based on SLA (leaf thickness). Physiological studies on the low and high SLA genotypes and SDS-PAGE of the wild *Arachis* species indicate there is the possibility of identifying the molecular marker for higher WUE and/or drought tolerance characteristics in groundnut.

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