

Genetic Variability and Association Analysis for Quantitative and Physiological Traits of Drought Tolerant Groundnut Genotypes

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Abstract Fifty drought tolerant groundnut genotypes developed were evaluated for their variability with regards to kernel yield and 12 yield component traits. Estimates of heritability, genetic advance and genetic advance as per cent mean were also obtained for the above traits. The results revealed high GCV, PCV, heritability and genetic advance as per cent mean for 100 kernel weight, pod yield per plant, haulm yield per plant and kernel yield per plant. Further, 100 kernel weight, pod yield per plant and haulm yield per plant had also recorded high positive direct effects and strong positive associations with kernel yield per plant and are identified as effective selection criteria for kernel yield improvement. The study also revealed the need for balanced selection, while effecting simultaneous improvement for plant height and kernel yield per plant.

Keywords Correlation, Path analysis, Groundnut, Variability, Yield.

Introduction

Groundnut (*Arachis hypogaea* L.) is an important

oilseed crop cultivated in more than 96 countries of the world. India ranks first in groundnut cultivated area (8.0 m ha) but occupies second place in production (7.5 m t), which is next to China in the world. The productivity of groundnut in India is low (1305 kg/ha), compared to than of USA (3,540 kg/ha), China (2,624 kg/ha), and Argentina (2,018 kg/ha). This is mainly attributed to its cultivation under rainfed conditions, with frequent dry spells. Therefore, there is an urgent need for development of high yielding drought tolerant varieties in groundnut. Further, kernel yield in groundnut is constituted by different yield components, including several physiological traits, which makes direct selection for kernel yield ineffective, owing to its complex nature of inheritance. In this context, information on variability of the experimental material, heritability of the traits conditioning kernel yield and their genetic advance, in addition to the nature and extent of association between the yield component traits and their association with kernel yield is a pre-requisite for effective crop improvement. Information on the direct and indirect effects of these component traits on kernel yield also aids in effecting targeted selections and superior crop improvement. The present investigation was undertaken in this context to study the variability, heritability, genetic advance, character associations and path effects of yield component and physiological traits on kernel yield of drought tolerant groundnut genotypes with a view to identify suitable selection criteria for higher kernel yield in drought tolerant groundnut.

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Materials and Methods

Experimental material for the present investigation comprised of 50 drought tolerant groundnut genotypes developed at Agricultural Research Station, Kadiri, Anantapur district of Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad. These genotypes were sown during *kharif* 2014 in a randomized block design with three replications at the PG Block of College Farm, Agricultural College, Mahanandi. Each genotype was sown in continuous two row plots of 6 m row length at a spacing of 30 cm between rows and 10 cm between plants, within the row. All recommended practices were followed to raise a healthy crop. Observations were recorded on pod yield per plant, kernel yield per plant, yield component characters, namely, days to maturity, plant height, sound mature kernel per cent (SMK), 100 kernel weight, shelling per cent and physiological traits, namely, SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA) and haulm yield per plant. The observations on plant height, sound mature kernel per cent, 100 kernel weight, shelling per cent, SPAD chlorophyll meter reading (SCMR), specific leaf area (SLA), haulm yield, pod yield and kernel yield per plant were recorded from five randomly selected plants for each genotype, in each replication, while observations on days to maturity were recorded on plot basis. The data thus obtained was subjected to standard statistical procedures [1]. Genotypic and phenotypic co-efficients of variation were calculated [2] and categorized [3]. Estimates of heritability in broad sense ($h^2_{(b)}$) [4] and genetic advance [5] were calculated. Categorization was also done [5]. Genotypic and phenotypic correlation coefficients were also calculated [5], while the direct and indirect contribution of different yield attributes was estimated by path co-efficient analysis [6] and categorized [7].

Results and Discussion

The results on analysis of variance (ANOVA) for yield, yield components and physiological characters studied are presented in Table 1. Highly significant mean squares due to genotypes were observed for all traits, indicating the existence of sufficient variation among the genotypes for yield, yield components and the physiological characters studied in the

present investigation and therefore, a scope for their effective selection.

Information on mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), environmental coefficient of variation (ECV), heritability, genetic advance and genetic advance as per cent mean for yield, yield components and physiological traits are furnished in Table 2. Range for a particular trait provides a preliminary idea about the extent of variability exhibited by the trait and in the present study, maximum range of variability was recorded for specific leaf area at 60 DAS followed by days to maturity. Further, the extent of variability as measured by PCV and GCV gives information regarding the relative amount of heritable variation in the experimental material and in the present study, higher PCV, compared to GCV were noticed for all the traits studied, indicating the influence of environment. The extent of environmental influence (environmental coefficient of variation—ECV) as explained by the amount of the difference between GCV and PCV ranged from 0.06 (100 kernel weight) to 21.14 (pods per plant) in the present study. Further, it was noticed to be low for days to maturity, plant height, sound mature kernels, shelling per cent, haulm yield per plant, SCMR and SLA, in addition to 100 kernel weight, indicating the minimal influence of environment on these traits. The findings are in agreement with earlier reports Satish [8] for days to maturity, plant height and 100 kernel weight. Further, days to maturity and SCMR had recorded low (<10%) PCV and GCV, while moderate values (10–20%) were recorded for filled pods per plant, kernels per plant and specific leaf area (SLA) at 60 DAS. The findings are in conformity with earlier reports Thakur et al. [9] for days to maturity and SCMR; and Injeti et al. [10] for filled pods per plant and specific leaf area (SLA). In contrast, high (> 20%) PCV and GCV were recorded for pods per plant, 100 kernel weight, pod yield per plant, haulm yield per plant and kernel yield per plant. The results are in conformity with the findings of John et al. [11] for pods, pod yield, haulm yield and kernel yield per plant and Yadav et al. [12] for 100 kernel weight.

High (> 60%) estimates of heritability were recorded for days to maturity, plant height, 100 kernel

Table 1. Analysis of variance (ANOVA) for yield, yield components and physiological characters in drought tolerant groundnut genotypes. *, ** Significant at 5% and 1% levels, respectively.

Source of variation	df	Mean squares					
		Days to maturity	Plant height (cm)	Pods per plant	Filled pods per plant	Kernels per plant	Sound mature kernel (%)
Replications	2	0.81	18.93	42.58	13.36	34.99	88.89
Genotypes	49	17.86**	34.41**	147.95**	63.99**	204.72**	222.15**
Error	98	0.94	11.36	69.30	23.78	88.22	117.03

Table 1. Continued.

Source of variation	100 kernel weight (g)	Shelling (%)	Pod yield per plant (g)	Mean squares			
				Haulm yield per plant (g)	SPAD chlorophyll meter reading (SCMR)	Specific leaf area (SLA)	Kernel yield per plant (g)
Replications	0.82	9.09	9.99	0.31	0.72	122.39	7.57
Genotypes	532.78**	174.69**	222.08**	190.16**	43.38**	3336.57**	90.23**
Error	0.53	50.45	40.11	0.80	1.08	268.13	15.87

weight, pod, haulm and kernel yields per plant, in addition to SCMR and SLA, while, moderate (30–60%) values were recorded for filled pods and kernels per plant, in addition to shelling per cent. The findings are in agreement with the reports of Hiremath et al. [13] for plant height, 100 kernel weight, pod yield and kernel yield and Patil et al. [14] for days to maturity and haulm yield. In contrast, moderate estimates of heritability were reported for SCMR and SLA by Toprope et al. [15]. Further, low (< 30%) heritability values were observed for pods per plant and sound mature kernel per cent. The findings are in conformity with reports of Thakur et al. [9].

A perusal of the results on genetic advance revealed high values (> 20%) for 100 kernel weight and specific leaf area. High genetic advance as per cent mean was also recorded for pods, filled pods and kernels per plant, in addition to 100 kernel weight, pod yield per plant, haulm yield per plant, kernel yield per plant and SLA. The results are in broad agreement with the reports of Patil et al. [14] for pods per plant, 100 kernel weight, pod yield per plant, haulm yield per plant and kernel yield per plant; and Thakur et al. [9]

for SLA. Further, moderate (10–20%) estimates of genetic advance as per cent mean were noticed for plant height, shelling per cent and SCMR, while low estimates were recorded for days to maturity and sound mature kernels per cent. The results are in broad agreement with the reports of Thakur et al. [9].

High heritability coupled with high genetic advance as per cent mean was recorded for 100 kernel weight, specific leaf area, pod yield per plant, haulm yield per plant and kernel yield per plant indicating that the high heritability observed is due to additive gene effects and therefore the effectiveness of selection for improvement of these characters. The results are in conformity with the reports of John et al. [11] for pod, haulm and kernel yields; and Thakur et al. [9] for 100 kernel weight. On contrary, high heritability coupled with moderate to low genetic advance as per cent mean was observed for plant height, SCMR and days to maturity, indicating the role of both additive and non-additive gene effects for control of these characters. The findings are in broad agreement with the reports of Satish [8]. Further, information on genetic variation along with heritability and genetic ad-

Table 2. Estimates of variability and genetic parameters for yield, yield components and physiological traits in drought tolerant groundnut.

Characters	Mean	Range	Coefficient of variation			Heritability (%)	Genetic advance	Genetic advance as percent of mean (%)
			Genotypic	Phenotypic	Environment			
Days to maturity	119.08	90.00–139.00	1.99	2.15	0.16	85.71	4.53	3.80
Plant height (cm)	33.60	20.53–41.00	8.25	12.99	4.74	40.35	3.63	10.79
Pods per plant	22.01	11.13–47.12	23.26	44.40	21.14	27.45	5.53	25.11
Filled pods per plant	18.56	10.23–28.87	19.73	32.85	13.13	36.05	4.53	24.40
Kernels per plant	35.03	19.98–50.01	17.79	32.18	14.39	30.56	7.10	20.26
Sound mature kernels (%)	86.80	67.74–96.53	6.82	14.21	7.39	23.04	5.85	6.74
100 kernel weight (g)	35.86	21.42–68.84	37.14	37.20	0.06	99.70	27.40	76.40
Shelling (%)	67.79	53.30–77.00	9.49	14.14	4.65	45.08	8.90	13.13
Pod yield per plant (g)	17.08	14.15–23.63	45.60	58.77	13.17	60.20	12.45	72.88
Haulm yield per plant (g)	27.08	10.03–41.12	29.34	29.52	0.19	98.75	16.26	60.06
SPAD chlorophyll meter reading (SCMR)	44.41	35.10–49.73	8.46	8.77	0.32	92.89	7.46	16.79
Specific leaf area (SLA)	171.28	127.13–227.00	18.67	20.98	2.31	79.23	58.64	34.24
Kernel yield per plant (g)	11.63	8.57–17.80	42.81	54.83	12.02	60.97	8.01	68.86

vance has been reported to give a better idea about the efficiency of selection [2]. In the present study, 100 kernel weight, pod yield per plant, haulm yield per plant and kernel yield per plant had recorded high GCV, PCV, heritability and genetic advance as per cent mean indicating the pre-ponderance of additive gene action and therefore, scope for effective improvement of these traits through selection.

Kernel yield in groundnut is a complex trait, based on various yield component traits and hence, direct selection for yield would be ineffective. Therefore, selection for various component traits responsible for conditioning of kernel yield in groundnut is advocated. In this context, the nature and magnitude of association among kernel yield and its component traits are important for the breeder to make an effective selection. Further, identification of important ker-

nel yield components and information about their inter-relationship will be useful in developing high yielding varieties. The genotypic and phenotypic correlations for yield and various yield components studied in the present investigation are presented in Table 3. A perusal of these results revealed phenotypic and genotypic correlations to be of similar direction and significance. However, genotypic correlations recorded a higher magnitude compared to phenotypic correlations indicating the masking effect of environment. Further, positive and significant association of kernel yield was noticed in the present study, with days to maturity, pods per plant, 100 kernel weight, pod yield per plant, shelling per cent, SCMR and haulm yield per plant indicating an increase in kernel yield with an increase in these characters. The findings are in agreement with the reports of Sadhegi and Niyaki [16] for haulm yield per plant and Shoba et al.

Table 3. Phenotypic and genotypic correlations among yield, yield components and physiological traits in drought tolerant groundnut genotypes. r_p = Phenotypic correlation ; r_g = Genotypic correlation ; *, ** Significant at 5% and 1% levels, respectively.

Characters	r	Plant height (cm)	Pods per plant	Filled pods per plant	Kernels per plant	Sound mature kernels (%)	100 kernel weight
Days to maturity	r_p	0.3851**	0.3828**	0.2140	0.1840	-0.0492	-0.0949
	r_g	0.4047**	0.4792**	0.2194	0.2105	-0.1125	-0.1041
Plant height	r_p		0.1196	-0.0397	-0.1047	0.0879	-0.2122
	r_g		0.1674	-0.2380	-0.1454	0.2213	-0.2634
Pods per plant	r_p			0.8891**	0.7221**	0.2817*	-0.1985
	r_g			1.0424**	0.9084**	0.3216*	-0.2715
Filled pods per plant	r_p				0.8218**	0.2763**	-0.2096
	r_g				0.9388**	0.4130**	-0.2698
Kernels per plant	r_p					0.0813	-0.2859**
	r_g					0.2665	-0.3052**
Sound mature kernels (%)	r_p						-0.1033
	r_g						-0.1501
100 kernel weight	r_p						
	r_g						
Pod yield per plant	r_p						
	r_g						
Shelling (%)	r_p						
	r_g						
SPAD chlorophyll meter reading (SCMR)	r_p						
	r_g						
Specific leaf area (SLA)	r_p						
	r_g						
Haulm yield per plant	r_p						
	r_g						

Table 3. Continued.

Characters	r	Pod yield per plant	Shelling (%)	SPAD chlorophyll meter reading (SCMR)	Specific leaf area (SLA)	Haulm yield per plant	Kernel yield per plant
Days to maturity	r_p	0.0660	0.1020	0.0636	0.1059	0.1833	0.6346**
	r_g	0.0718	0.1483	0.0709	0.1163	0.1989	0.6460**
Plant height	r_p	-0.1635	0.1455	-0.2897**	0.1528	0.3657**	-0.3054*
	r_g	-0.2719	0.2194	-0.3458**	0.1961	0.4522**	-0.3201*
Pods per plant	r_p	0.4941**	-0.1739	0.0637	0.0750	0.3280**	0.6300**
	r_g	0.4998**	-0.1836	0.0835	0.1484	0.4237**	0.6349**
Filled pods per plant	r_p	0.5460**	-0.2411	0.0471	0.0878	0.2069	0.1702
	r_g	0.5825**	-0.2434	0.0503	0.1332	0.2596	0.1212
Kernels per plant	r_p	0.5113**	-0.1538	0.0175	0.1175	0.1279	0.2536
	r_g	0.5802**	-0.2414	0.0196	0.1581	0.1620	0.2022
Sound mature kernels (%)	r_p	0.1315	0.1072	0.1239	-0.3609**	-0.1488	0.1458
	r_g	0.1424	0.1630	0.1632	-0.5651**	-0.2092	0.1475
100 kernel weight	r_p	0.4823**	0.1688	0.6504**	0.1102	0.0818	0.3163*
	r_g	0.5285**	0.2027	0.6593**	0.1152	0.0821	0.3307*

Table 3. Continued.

Characters	r	Pod yield per plant	Shelling (%)	SPAD chlorophyll meter reading (SCMR)	Specific leaf area (SLA)	Haulm yield per plant	Kernel yield per plant
Pod yield per plant	r_p		-0.2429*	-0.3144**	0.1181	0.2200	0.8079**
Shelling (%)	r_g		-0.2496*	-0.3546**	0.1346	0.2413	0.8237**
SPAD chlorophyll meter reading (SCMR)	r_p			-0.2785*	0.0573	0.0997	0.6657**
Specific leaf area (SLA)	r_g						
Haulm yield per plant	r_p			-0.3212*	0.0851	0.1157	0.6934**
	r_g				-0.0913	-0.2049	0.3000*
					-0.1003	-0.2063	0.3014*
						0.1999	0.2419
						0.2159	0.2455
							0.3896**
							0.5219**

[17] for other traits. Further, significant and negative associations were noticed for kernel yield per plant with plant height, indicating the need for balanced selection, while effecting simultaneous improvement for these traits. The results are in conformity with earlier reports [18].

A perusal of the results on inter-character associations revealed significant and positive association of days to maturity with plant height [13] and pods per plant [19]; pods per plant with filled pods per plant [20], kernels per plant, sound mature kernels per cent [21], pod yield per plant [8] and haulm yield per plant [22]; filled pods per plant with kernels per plant, sound mature kernels per cent [23] and pod yield per plant [8]; kernels per plant with pod yield per plant [8]; and 100 kernel weight with pod yield per plant [8] and SCMR [17], in the present investigation, indicating a scope for simultaneous improvement of these traits through selection. The findings are in conformity with the reports of earlier workers. In contrast, significant and negative association of plant height with SCMR [24]; kernels per plant with 100 kernel weight; sound mature kernels per cent with SLA [25]; pod yield per plant with shelling (%) [23]; and shelling (%) with SCMR [25] were observed in the present study, probably due to competition for a common possibility such as nutrient supply, indicating the need for balanced selection while effecting improve-

ment for these traits. The results are also in agreement with the reports of earlier workers.

Path co-efficient analysis provides an effective means of finding out the direct and indirect causes of association and presents a critical examination of the specific forces acting to produce a given correlation and also measures the relative importance of each causal factor. Hence, the study of direct and indirect effects of yield components on kernel yield per plant was undertaken in the present investigation and the results obtained are presented in Table 4. A perusal of these results on path co-efficients for yield and yield components revealed genotypic and phenotypic path co-efficients to be of similar direction and magnitude. Further, the genotypic path co-efficients were observed to be of higher magnitude, compared to phenotypic path co-efficients indicating the masking effect of environment. The results also revealed high residual effect for both phenotypic (0.3606) and genotypic (0.3745) path co-efficients, respectively, indicating that variables studied in the present investigation explained about 64 (phenotypic) and 63 (genotypic) per cent of the variability in kernel yield and therefore, other attributes besides the characters studied are contributing for kernel yield. The results also revealed high (>0.30) positive direct effects of days to maturity, pods per plant, 100 kernel weight, pod yield per plant, shelling per cent and haulm yield on

Table 4. Phenotypic and genotypic path coefficients of yield component and physiological characters on kernel yield in drought tolerant groundnut. Residual effect (Phenotypic) = 0.3606; Residual effect (genotypic) = 0.3745 : Diagonal values = Direct effects : Off-Diagonal values = Indirect effects : *, ** Significant at 0.05 and 0.01 levels, respectively.

Characters	<i>r</i>	Days to maturity	Plant height (cm)	Pods per plant	Filled pods per plant	Kernels per plant	Sound mature kernels (%)	100 kernel weight
Days to maturity	r_p	0.4110	0.012	0.1730	0.1000	0.0080	0.0450	-0.1300
	r_g	0.4140	0.0014	0.1940	0.1500	0.0960	0.0670	-0.3100
Plant height	r_p	-0.0910	-0.9380	-0.0020	0.6420	0.1100	0.0260	-0.0063
	r_g	-0.0970	-0.9590	-0.0023	0.6540	0.1400	0.0750	-0.0890
Pods per plant	r_p	0.2130	-0.0450	0.3973	0.0720	0.0027	-0.0205	-0.0074
	r_g	0.2150	-0.0540	0.3988	0.0860	0.0039	-0.0214	-0.0083
Filled pods per plant	r_p	0.0250	0.1730	0.0951	0.0298	-0.0560	-0.0170	0.0840
	r_g	0.0280	0.0190	0.0991	0.0396	-0.0650	-0.0230	0.0930
Kernels per plant	r_p	0.2420	-0.1040	0.1450	0.0570	0.0328	0.0710	0.0071
	r_g	0.2580	-0.1070	0.1560	0.0680	0.0034	0.0820	0.0092
Sound mature kernels (%)	r_p	0.1040	-0.0007	-0.0017	-0.0020	-0.0007	-0.0082	0.0080
	r_g	0.1070	-0.0152	-0.0222	-0.0300	-0.0203	-0.0685	0.0130
100 kernel weight	r_p	-0.1070	-0.1560	-0.0046	-0.0054	-0.0166	-0.0076	0.4734
	r_g	-0.1210	-0.4790	-0.0194	-0.0191	-0.0312	-0.0950	0.4901
Pod yield per plant	r_p	0.0542	-0.2009	0.6480	0.2090	-0.0971	0.0001	0.0004
	r_g	0.0648	-0.2012	0.6540	0.4760	-0.0988	0.0009	0.0009
Shelling (%)	r_p	0.2560	0.0565	-0.0476	-0.0937	-0.0598	0.0417	0.0656
	r_g	0.2730	0.0715	-0.0501	-0.0993	-0.0787	0.0531	0.0660
SPAD chloro-phyll meter reading (SCMR)	r_p	0.3008	0.0179	0.0014	0.00111	0.0204	0.0107	-0.0148
	r_g	0.3009	0.0187	0.0170	0.0114	0.0306	0.0193	-0.0152
Specific leaf area (SLA)	r_p	0.3957	-0.0223	-0.0210	-0.0003	-0.1004	-0.0110	-0.0153
	r_g	0.3961	-0.0253	-0.0179	-0.0070	-0.1584	-0.0300	-0.0261
Haulm yield per plant	r_p	0.1741	0.0325	0.0205	0.1710	0.0440	-0.1150	0.0038
	r_g	0.1792	0.0358	0.0336	0.2060	0.0880	-0.1260	0.0045

Table 4. Continued.

Characters	<i>r</i>	Pod yield per plant	Shelling (%)	SPAD chloro-phyll meter reading (SCMR)	Specific leaf area (SLA)	Haulm yield per plant	Kernel yield per plant
Days to maturity	r_p	0.0010	0.0083	0.0020	0.0051	0.0100	0.6346**
	r_g	0.0019	0.0092	0.0032	0.0053	0.0140	0.646**
Plant height	r_p	-0.0019	0.0543	-0.0830	-0.0046	-0.0109	-0.3054*
	r_g	-0.0053	0.0774	-0.0970	-0.0056	-0.0113	-0.3201*
Pods per plant	r_p	-0.0284	0.0650	-0.0044	-0.0028	-0.0115	0.6300**
	r_g	-0.0329	0.0910	-0.0055	-0.0098	-0.0279	0.6349**
Filled pods per plant	r_p	0.0137	0.0076	-0.0300	-0.0006	-0.0014	0.1702
	r_g	0.0167	0.0084	-0.0470	-0.0046	-0.0090	0.1212
Kernels per plant	r_p	-0.1700	-0.0075	-0.0040	-0.0247	0.0089	0.2536
	r_g	-0.1900	-0.0090	-0.0510	-0.0576	0.0096	0.2022
Sound mature kernels (%)	r_p	0.0110	0.0009	0.0010	0.0030	0.0312	0.1458
	r_g	0.0770	0.0102	0.0412	0.0070	0.0443	0.1435
100 kernel weight	r_p	0.0004	0.0004	-0.0477	0.1810	0.0060	0.3163*
	r_g	0.0559	0.3610	-0.0491	0.2350	0.0025	0.3307*

Table 4. Continued.

Characters	<i>r</i>	Pod yield per plant	Shelling (%)	SPAD chloro-phyll meter reading (SCMR)	Specific leaf area (SLA)	Haulm yield per plant	Kernel yield per plant
Pod yield per plant	<i>r_p</i>	0.9823	-0.9361	-0.1557	0.2028	0.1009	0.8079**
	<i>r_g</i>	0.9865	-0.9965	-0.7498	0.2528	0.2341	0.6237**
Shelling (%)	<i>r_p</i>	-0.0944	0.6886	-0.2082	0.0223	0.0387	0.6657**
	<i>r_g</i>	-0.0948	0.6959	-0.2086	0.0257	0.0397	0.6934**
SPAD chloro-phyll meter reading (SCMR)	<i>r_p</i>	-0.0032	-0.0003	0.0028	-0.0451	-0.0017	0.3000*
	<i>r_g</i>	-0.0058	-0.0026	0.0059	-0.0978	-0.0076	0.3014*
Specific leaf area (SLA)	<i>r_p</i>	0.0070	0.0002	0.0003	0.0031	0.0059	0.2419
	<i>r_g</i>	0.0710	0.0004	-0.0073	0.0039	0.0061	0.2055
Haulm yield per plant	<i>r_p</i>	0.0005	0.0550	-0.0070	0.0102	0.3619	0.3896**
	<i>r_g</i>	0.0001	0.0920	-0.0163	0.0250	0.3622	0.5219**

kernel yield per plant. The results are in conformity with the findings of Babaria and Dobariya [26] for days to maturity and pods per plant ; Kumar et al. [27] for 100 kernel weight and haulm yield per plant ; and Kumar et al. [20] for pod yield per plant and shelling per cent. These traits had also recorded significant and strong positive association with kernel yield per plant. In contrast, plant height had recorded high negative direct effect on kernel yield, in addition to significant and negative association with kernel yield per plant. The results are in agreement with the reports of Suneetha et al. [28]. High direct effects of these traits therefore appear to be the main factor for their strong association with kernel yield. Hence, these traits should be considered as important selection criteria in all groundnut improvement programs and direct selection for these traits is recommended for kernel yield improvement. Further, filled pods per plant, kernels per plant and SCMR had recorded low positive direct effects, while sound mature kernel per cent had recorded low negative direct effect on kernel yield per plant, indicating the role of indirect effects and the need for consideration of indirect effects of these traits in drought tolerant groundnut kernel yield improvement programs.

Conclusion

Results of the present investigation reveal the effectiveness of direct selection for improvement of 100

kernel weight, pod yield per plant, haulm yield per plant and kernel yield per plant, owing to their high GCV, PCV, heritability and genetic advance as per cent mean values. Further, 100 kernel weight, pod yield per plant and haulm yield per plant are identified as effective selection criteria for kernel yield improvement in drought tolerant groundnut, due to their high positive direct effects and strong positive association with kernel yield per plant.

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