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RESEARCH ARTICLE

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Principal Component Analysis and Path Coefficient Analysis for Groundnut Yield and Seed Quality Attributes (*Arachis hypogaea* L.)

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ABSTRACT

Background: A complex quantitative characteristic yield is heavily impacted by the environment. The productivity of groundnut can be increased less effectively through direct selection for grain yield. The current study aimed to study the variation among diverse groundnut genotypes.

Methods: Phenotypic data was collected on seven quantitative and six qualitative characters for 24 genotypes under study carried out in randomised block design (RBD). GRAPES software has been used for analysis.

Result: Analysis of variance revealed significant differences among the genotypes for all the characters indicating the prevalence of ample genetic variability within the genotypes. Significant positive associations were observed for primary branches, secondary branches, 100-pod weight, shelling per cent, protein and zinc content. Path analysis revealed that plant height, primary branches per plant, hundred pod weight, shelling percent, protein content and zinc content are the most important characters which could be used as selection criteria for effective improvement of pod yield. Using GRAPES software, Fourteen Principal components are extracted based on mean values of which the first five PCs showed 73.24% variation with eigen values more than 1. Biplot constructed by Principal component analysis revealed Hundred pod weight and hundred kernel weight as important traits for study.

Key words: Groundnut, Path coefficient analysis, Principal component analysis.

INTRODUCTION

Groundnut is the major oilseed crop of India and is known by several names based on the location such as Pindar in U.S, Monkey nut in UK, Manila nut in Philippines. It contains high oil (45-55 %) and protein (25-30%) content. Globally, it is cultivated in an area of 29.92 Mha with annual production of 55.30 million tonnes and 1851 kg/ha of productivity. India ranks second among different countries in groundnut production with an area of 6.01 million ha, 10.24 million tons of production and 1703 kg/ha of productivity (Ministry of Agriculture and Farmers Welfare, Govt of India 2020-21). In Andhra Pradesh, it is cultivated in an area of 0.87 Mha with production of 0.77 Mt and average productivity of 891 kg/ha (AICRP- Annual Report 2020-2021). The nature of the relationship between yield and its constituent parts facilitates the selection of numerous characters simultaneously involved in yield improvement. Yield has a complex personality that is shaped by a lot of interrelated characteristics. These characters' interdependence will have an impact on kernel yield either directly or indirectly. Path coefficient analysis is utilised for the separation of direct impacts from indirect effects and gives the relationship of the characters.

MATERIALS AND METHODS

The present study was carried out in randomised block design(RBD) with 24 groundnut varieties from which 22 varieties *viz.*,TPT-1, TPT-2, TPT-3, TPT-4,Narayani, Kalahasti, Prasuna, Abhaya, Greeshma, Nithya Haritha, Bheema, Rohini, Dharani, ICGV-00350, Pragathi (TCGS-894), TCGS1073, Kadiri-6, Kadiri-7, Kadiri-8, Kadiri-9, Kadiri Harithandra and Kadiri Amaravathi were released from ANGRAU and other variety TAG-24 released from BARC, Baba Atomic Research Station and JL-24 released from Oilseed Research Station, Jalgoan to investigate direct and indirect effects by path analysis and variation by principal

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Component analysis. The experimental field work was carried out in Acharya N.G. Ranga Agricultural University (ANGRAU), Regional Agricultural Research Station (RARS), Tirupati in *kharif* season during the year 2019 employing these 24 genotypes.

Five plants were randomly selected for each genotype from each replication. Observations on seven quantitative parameters *viz.*, plant height (cm), number of primary branches/plant, number of secondary branches/plant, pod yield/plant (g), hundred pod weight (g), hundred kernel weight (g) and shelling percentage were recorded for all the genotypes. Averages of 5 plants were calculated and mean values of three replications were taken for statistical analysis. Statistical analysis such as Path Coefficient analysis and Principal component analysis was carried out using GRAPES software developed by Kerala Agricultural University, Kerala India.

RESULTS AND DISCUSSION

Based on the data recorded on the genotypes in the present investigation, the results of the analysis of variance showed that all of the characters' differed significantly, demonstrating the prevalence of ample genetic diversity among the genotypes (Table 1).

Character association study

The genotypic and phenotypic correlations were estimated to determine direct and indirect effects of yield and yield contributing characters and presented in Table 2 and Fig 1. Pod yield per plant showed positive and significant correlation with primary branch number (0.591), hundred pod weight (0.654), hundred kernel weight (0.694) whereas positive correlation with secondary branch number (0.11) and quality parameters *viz*., protein content (0.402), sucrose content (0.122), total free aminoacids (0.052), iron (0.315) and zinc content (0.143) which suggests that increase or improvement in these characters lead to improvement in pod yield/ plant (Table 2, Fig 1). Similar kind of significant positive correlation of pod yield/plant with hundred pod weight and protein content was observed by Kumar *et al*. (2019), Bhargavi *et al*. (2016) and Shoba *et al.* (2012). Among the quality traits, as protein content showed a negative correlation with oil content (-0.396).

Path coefficient analysis

The results of path coefficient analysis of yield and yield contributing characters are presented in Table 3. The study of the interactions and relative contributions of many traits to crop development is greatly aided by genetic association. Estimates of correlation coefficients did not reflect the direct and indirect impacts of various features on the yield; they only showed the relationship between yield and yield components. This is so because the attributes that are associated do not exist alone; rather, they are connected to other elements. Dewey and Lu (1959) path coefficient analysis suggests useful assessments of the direct and indirect causes of association and illustrates the relative value of each element contributing to the final yield. The cause-and-effect link between yield as a whole and yield component qualities was looked at using path coefficient analysis in order to obtain the developmental relations.

Plant height had positive direct effect on pod yield per plant (0.246) while the correlation of plant height with pod yield was positive and significant (0.314). The correlation between plant height and pod yield was positive and significant mainly due to positive indirect effect contribution through hundred kernel weight (0.513), shelling percent (0.713), protein content (0.096), seed micronutrient content *i.e*., Zinc content (0.078). The positive direct effect of plant height on pod yield had been reported by Jain *et al.* (2016), Raut *et al.* (2010) and John *et al*. (2019).

Table 1: Analysis of variance for yield and seed quality traits in groundnut.

Character	Mean sum of squares		
	Replications (df: 2)	Treatments (df: 23)	Error (df: 46)
Plant height	133.08	298.827**	27.71
Primary branches per plant	2.94	4.243**	0.56
Secondary branches per plant	0.13	2.660**	0.08
Pod yield per plant	4.97	30.948**	5.04
Hundred pod Weight	285.89	1329.038**	217.79
Hundred kernel weight	36.15	144.416**	15.12
Shelling percentage	12.26	83.413**	16.33
Oil content	0.49	1.708**	0.06
Protein content	0.06	0.282**	0.07
Total free aminoacids (TFA)	6.31	22218.767**	64.76
Total soluble sugars (TSS)	0.02	0.062**	0.00
Total sucrose content	1.38	264.623**	2.91
Fe content	134.11	4359.679**	357.81
Zn content	48.76	194.429*	91.88

Table 2: Correlation coefficients studied for yield and seed quality characters.

Trait	PYP	PH	PBP	SBP	100 PW	100 KW	SP	Oil	Protein	Sucrose	TFA	TSS	Fe	Zn
PYP	1	-0.147	0.591**	0.014	0.654***	0.694***	-0.113	-0.433*	0.402	0.122	0.052	-0.17	0.315	0.143
PH	-0.147	1	-0.187	-0.007	0.073	0.17	-0.271	0.088	0.059	-0.047	0.477*	0.074	-0.045	0.124
PBP	0.591**	-0.187	1	-0.024	0.399	0.362	-0.079	-0.667***	0.194	0.084	0.049	-0.302	0.234	0.411*
SBP	0.014	-0.007	-0.024	1	0.405*	0.293	-0.422*	-0.07	0.261	0.089	-0.067	0.126	-0.084	0.068
100 PW	0.654***	0.073	0.399	0.405*	1	0.892***	-0.607**	-0.521**	0.41*	0.135	0.2	0.129	-0.015	0.174
100 KW	0.694***	0.17	0.362	0.293	0.892***	1	-0.521**	-0.366	0.229	0.11	0.128	-0.018	0	0.034
SP	-0.113	-0.271	-0.079	-0.422*	-0.607**	-0.521**	1	0.279	-0.001	-0.116	-0.432*	-0.342	0.061	0.155
Oil	-0.433*	0.088	-0.667***	-0.07	-0.521**	-0.366	0.279	1	-0.396	0.065	-0.148	0.102	0.013	-0.482*
Protein	0.402	0.059	0.194	0.261	0.41*	0.229	-0.001	-0.396	1	0.021	0.109	0.024	0.013	0.318
Sucrose	0.122	-0.047	0.084	0.089	0.135	0.11	-0.116	0.065	0.021	1	0.403	-0.269	0.053	-0.096
TFA	0.052	0.477*	0.049	-0.067	0.2	0.128	-0.432*	-0.148	0.109	0.403	1	0.217	0.12	0.089
TSS	-0.17	0.074	-0.302	0.126	0.129	-0.018	-0.342	0.102	0.024	-0.269	0.217	1	-0.139	0.092
Fe	0.315	-0.045	0.234	-0.084	-0.015	0	0.061	0.013	0.013	0.053	0.12	-0.139	1	-0.113
Zn	0.143	0.124	0.411*	0.068	0.174	0.034	0.155	-0.482*	0.318	-0.096	0.089	0.092	-0.113	1

PYP: Pod yield per plant; PH: Plant height; PBP: Primary branches per plant; SBP: Secondary branches per plant; 100 PW: Hundred pod weight; 100 KW: Hundred kernel weight; SP: Shelling percentage; Oil: Oil content; Protein: Protein content; Sucrose: Sucrose content; TFA: Total free amino acids; TSS: Total soluble sugars; Fe: Iron content; Zn: Zinc content.

Table 3: Direct (diagonal bold) and Indirect effects of component characters on character of interest.

	PH	PBP	SBP	100PW	100KW	SP	Oil	Protein	Sucrose	TFA	TSS	Fe	Zn	gen_corr PYP
PH	**0.246**	-0.064	-0.061	-1.007	0.513	0.713	-0.017	0.096	-0.058	-0.035	0	-0.091	0.078	0.314
PBP	0.072	**-0.217**	0.742	-3.549	0.653	2.836	-0.159	0.297	0.037	-0.001	0.008	-0.009	0.216	0.926
SBP	-0.016	-0.171	**0.94**	-3.34	1.094	2.118	-0.141	0.124	-0.011	-0.004	0.002	-0.04	0.166	0.721
100PW	0.046	-0.143	0.585	**5.366**	1.203	4.016	-0.117	0.347	0.068	-0.049	-0.006	0.025	0.132	0.74
100KW	-0.069	0.078	-0.563	3.535	**-1.825**	-1.707	0.087	-0.012	0.062	0.072	0.016	0.049	-0.005	-0.282
SP	0.042	-0.146	0.472	-5.106	0.738	**4.22**	-0.105	0.429	0.105	-0.031	0.001	0.048	0.151	0.819
Oil	-0.022	0.179	-0.689	3.259	-0.824	-2.289	**0.193**	-0.214	-0.018	0.032	-0.004	-0.025	-0.195	-0.618
Protein	0.047	-0.127	0.231	-3.684	0.043	3.586	-0.082	**0.505**	0.036	-0.027	-0.002	0.039	0.118	0.683
Sucrose	-0.052	-0.029	-0.039	-1.334	-0.416	1.622	-0.013	0.067	**0.274**	-0.061	0.016	0.019	0.02	0.074
TFA	0.04	-0.001	0.019	-1.206	0.61	0.599	-0.029	0.064	0.077	**-0.216**	-0.01	-0.008	0.037	-0.025
TSS	0.002	0.037	-0.042	-0.703	0.662	-0.067	0.019	0.018	-0.098	-0.047	**-0.045**	-0.005	0.036	-0.232
Fe	0.111	-0.009	0.185	0.66	0.442	-1.008	0.024	-0.098	-0.026	-0.009	-0.001	**-0.202**	-0.046	0.023
Zn	0.064	-0.156	0.521	-2.369	0.03	2.119	-0.125	0.198	0.018	-0.026	-0.005	0.031	**0.3**	0.6

Residual effect square= 0.0076.

PH: Plant height; 100 KW: Hundred kernel weight; TFA: Total free amino acids; PBP: Primary branches per plant ; SP: Shelling percentage; TSS: Total soluble sugars; SBP: Secondary branches per plant; Oil: Oil content; Fe: Iron content; PYP: Pod yield per plant; Protein: Protein content; Zn: Zinc content; 100 PW: Hundred pod weight; Sucrose: Sucrose content Trait order.

Hundred pod weight exhibited a positive direct effect on pod yield per plant (5.36) while the correlation with pod yield per plant was also positive and significant (0.74). Shelling percentage exhibited a positive direct effect on pod yield per plant (4.22) while the correlation with pod yield per plant was also positive and significant (0.819). Similar findings are seen with Korat *et al.* (2010), Zaman *et al.* (2011), Shoba *et al.* (2012) and Reddy *et al.* (2017a and 2017b). Hundred kernel weight had direct negative phenotypic effect (-1.825) on pod yield per plant. whereas the correlation was negative significant (-0.282). Hundred kernel weight exerted negative direct effect (-1.825) on pod yield per plant as observed earlier by Patel and Shelke (1992).

Oil content had direct positive effect (0.193) on pod yield per plant. Its correlation with pod yield per plant was negative and significant (-0.618). The correlation between oil content and pod yield per plant was negative and significant mainly due to negative indirect effect contribution through plant height (-0.022), number of secondary branches per plant (-0.689), hundred kernel weight (-0.824)

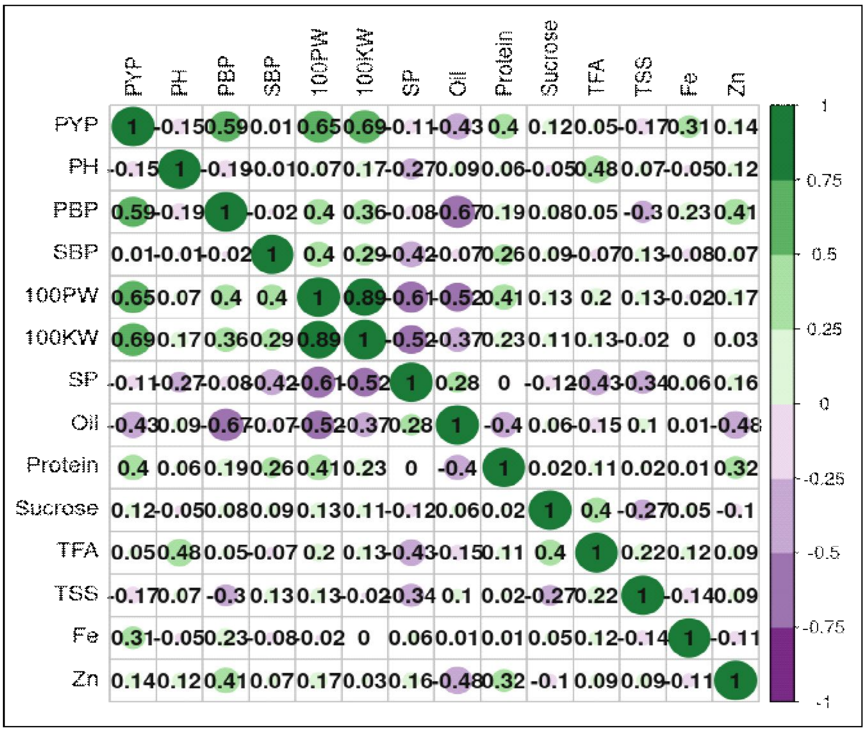

Fig 1: Correlation coefficients for yield and seed quality characters in groundnut.

Table 4: Eigen values and proportion of variation for different principal components.

Principal components	Eigenvalue	Percentage of variance	Cumulative percentage of variance
PC1	3.945	28.179	28.179
PC2	2.2	15.712	43.891
PC3	1.584	11.313	55.204
PC4	1.454	10.384	65.588
PC5	1.071	7.654	73.241
PC6	0.936	6.686	79.927
PC7	0.875	6.25	86.177
PC8	0.731	5.222	91.398
PC9	0.545	3.892	95.29
PC10	0.227	1.622	96.912
PC11	0.177	1.264	98.177
PC12	0.114	0.815	98.992
PC13	0.099	0.706	99.698
PC14	0.042	0.302	100

and shelling percentage (-2.289). Protein content had direct positive effect on pod yield per plant (0.505) while its correlation with pod yield was positive significant (0.683). The correlation between protein content and pod yield per plant was positive is mainly due to positive indirect effect influence through plant height (0.047), hundred kernel weight (0.043), shelling percent (3.586), sucrose content (0.036) and seed micronutrient Fe (0.039) and Zn content (0.118). Total free aminoacids (-0.216), Total soluble sugars (-0.045) and iron content (-0.202) exerted negative direct effect on pod yield per plant. The lower residual effect (0.0076) indicated that sufficient contribution in pod yield per plant has been explained by the independent variables included in the analysis.

Path coefficient analysis revealed that Hundred pod weight (5.36) exerted the highest positive direct effect on pod yield per plant followed by shelling percentage (4.22), primary branches per plant, hundred pod weight, oil content and protein content. The negative direct effect was showed on pod yield by hundred kernel weight, sucrose content, total soluble sugars and iron content.

Principal component analysis (PCA)

The PCA based on correlation matrix on the mean values of the groundnut genotypes was performed which provided a reduced a dimension model that could indicate measured differences among the genotypes in the population. The results revealed the importance of first five Principal Components (PCs) in discriminating the groundnut population. Since first five PCs selected as it explains 73.24% of variation and had Eigen values greater than 1. The eigen values and associated cumulative percentage of variation explained by eigen vectors have been presented in Table 4 and Table 5 which shows the scree plot graph (Fig 2) for variation explained by various principal components.

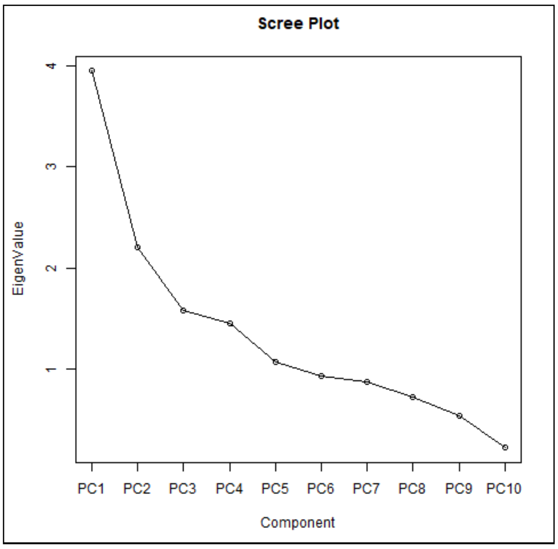

Fig 2: Scree plot for variation explained by principal components.

Table 5: Eigen vectors for different Principal components.

variables	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14
PH	0.044	-0.368	0.026	-0.438	0.101	-0.058	0.601	-0.28	0.065	-0.101	0.25	-0.149	0.302	0.165
PBP	0.325	0.369	0.046	-0.133	0.061	0.256	-0.18	-0.219	0.055	-0.69	0.226	0.232	0.06	0.021
SBP	0.175	-0.237	-0.176	0.369	-0.389	-0.293	-0.138	-0.538	0.128	-0.152	-0.322	-0.044	0.232	0.039
PYP	0.383	0.243	0.176	0.107	0.198	-0.152	0.123	0.296	0.174	-0.153	-0.295	-0.647	0.065	0.156
100PW	0.459	-0.133	-0.019	0.191	0.028	0.023	0.072	0.126	0.093	0.237	0.102	0.389	-0.182	0.673
100KW	0.414	-0.112	0.105	0.24	0.122	0.117	0.332	0.107	0.232	0.122	-0.059	0.307	0.109	-0.648
SP	-0.27	0.458	-0.069	-0.121	-0.114	-0.236	0.205	0.204	0.256	0.035	-0.26	0.392	0.483	0.156
Oil	-0.36	-0.196	0.215	0.179	0.001	-0.268	0.179	0.111	0.456	-0.429	0.04	0.112	-0.479	0.019
Protein	0.26	0.077	-0.233	-0.111	-0.25	-0.623	0.135	0.256	-0.437	-0.157	0.22	0.075	-0.161	-0.172
Sucrose	0.087	-0.063	0.518	-0.096	-0.605	0.015	-0.222	0.199	0.217	0.126	0.369	-0.113	0.208	-0.027
TFA	0.151	-0.335	0.273	-0.533	-0.015	-0.02	-0.21	0.122	-0.117	-0.12	-0.6	0.222	-0.096	-0.014
TSS	-0.002	-0.387	-0.351	-0.013	0.339	-0.155	-0.453	0.352	0.246	-0.13	0.215	-0.001	0.365	-0.03
Fe	0.054	0.182	0.401	-0.078	0.443	-0.517	-0.247	-0.394	0.065	0.283	0.146	0.095	-0.016	-0.057
Zn	0.174	0.173	-0.438	-0.436	-0.164	0.001	-0.075	-0.13	0.541	0.242	0	-0.124	-0.356	-0.12

The first principal component gave high positive weight (0.459) to Hundred pod weight and Hundred kernel weight (0.414), similarly second, third, fourth and fifth Principal components gave high positive weights to Shelling percentage (0.458), sucrose content (0.51), secondary branches per plant (0.369) and Iron content (0.443) respectively. From the eigen loadings, the first principal component is strongly correlated with primary branch number, pod yield/plant, hundred pod weight and kernel weight. Out of these, PC1 was most strongly correlated with hundred pod weight and hundred kernel weight.

Biplot analysis

An attempt has been made to observe the variation explained by seven quantitative and six qualitative characters along one and two principal component vectors *i.e.*, Biplot (Fig 3 and Fig 4). From Biplot, 14 characters were grouped into five groups. Primary branches per plant, Zinc content, Protein content, Pod yield per plant were grouped in same cluster; hundred kernel weight and hundred pod weight as single group and Secondary branches per plant, total free aminoacids, total soluble sugars and plant height as one group. Those genotypes nearer to each trait can be said as best suited for those traits respectively. The genotypes TAG-24 and Abhaya are best suited for shelling percentage. Genotype Rohini was highly suitable for oil content and Dheeraj for total soluble sugars. Genotype Nithya Haritha was highly suitable for protein content and contributed more to this trait. There is high correlation between hundred kernel weight and hundred pod weight and also between total free Aminoacids and plant height.

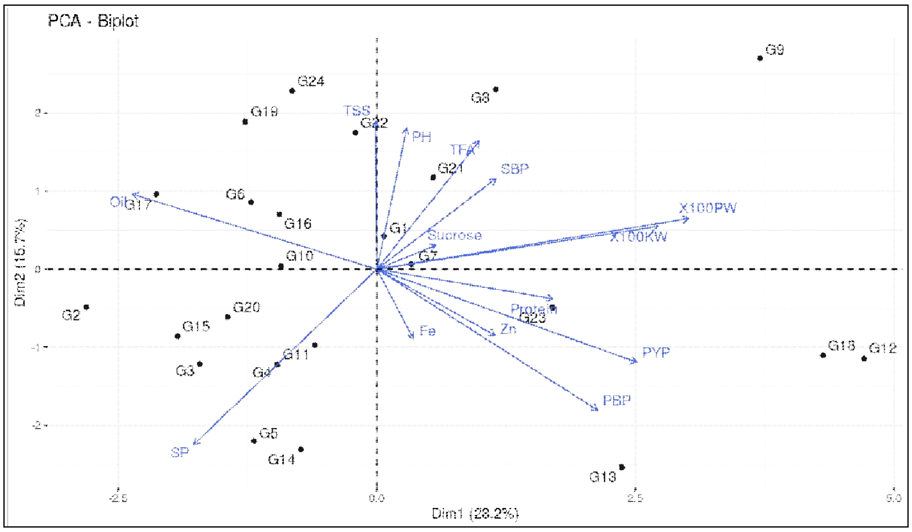

Fig 3: Genotype by trait Biplot showing distribution of genotypes across first two PCs.

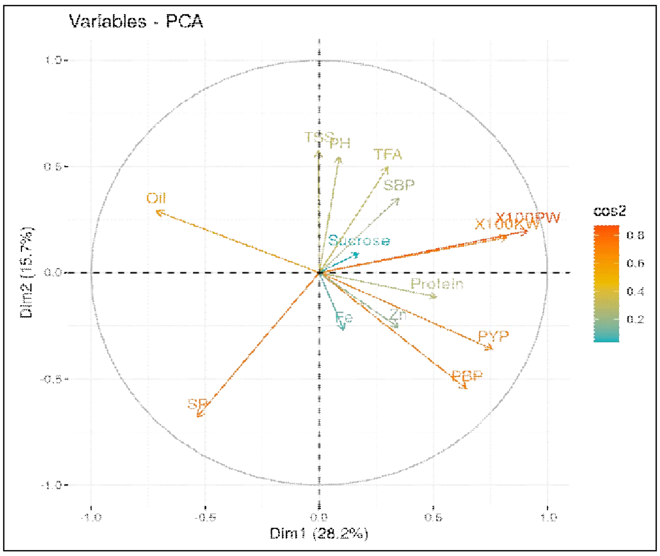

Fig 4: PCA Biplot showing variation among traits.

CONCLUSION

Among the yield component traits, significant positive correlations were observed for primary branches/ plant, secondary branches/ plant, hundred pod weight and shelling per cent. Path analysis revealed that plant height, primary branches per plant, hundred pod weight, shelling percent, protein content and zinc content are the most important characters which could be used as selection criteria for effective improvement of pod yield. Biplot constructed by Principal component analysis revealed hundred pod weight and hundred kernel weight as important traits for study. Therefore, it is suggested that preference should be given to these characters in the selection programme to isolate superior lines with genetic potentiality for higher yield in peanut genotypes.

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Conflict of interest: None.

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