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Character Association and Path Coefficient Analysis for Morpho-Physiological Traits in Groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Correlation and path coefficients were worked out for twenty three traits involving twenty eight hybrids in groundnut. Pod yield per plant had significant positive association with plant height, number of well-filled and mature pods per plant, 100-kernel weight and kernel yield per plant in F_1s. Significant positive association with sound mature kernel per cent was observed among the F_1 crosses. These characters can be considered as criteria for selection for higher yield, as these were mutually and directly associated with pod yield. SCMR had significant negative association with specific leaf area. Path coefficient analysis revealed that kernel yield per plant had maximum positive direct effect on pod yield per plant indicating that kernel yield is the important yield contributing character. A perusal of path coefficients in F_1 generation revealed the moderate direct positive effect of number of well-filled and mature pods per plant on pod yield in groundnut. The high direct effect of pods per plant was appeared to be the main factor for its strong positive correlation with pod yield. Hence, a direct selection for this trait would be effective.

Key words : Groundnut, Characters association, Path analysis, Physiological traits,Yield.

Crop improvement is a continuous process which takes care of the changing needs and new problems arising in crop productivity. Pod yield in groundnut is a complex and depends upon the interplay of number of component attributes. Further, pod yield besides physiological traits in groundnut are quantitatively inherited complex traits and is highly influenced by environment. A clear picture of contribution of each component is the final expression of character would emerge through the study of correlation and causation of path concept revealing different ways in which component attributes influence the complex traits. In order to achieve the goal of increased production by increasing the yield potential of crop, knowledge of direction and magnitude of association between various traits is essential for plant breeders. Accordingly, the present investigation was aimed to study the association of pod yield and its component traits in F_1 crosses.

MATERIAL AND METHODS

The experimental material consisted of twenty eight F_1 groundnut crosses and were grown in a randomized block design at Regional Agricultural research Station, Tirupati, Andhra Pradesh under irrigated conditions during *rabi* 2009. All the genotypes were randomized in three replications and were raised in a single row of 3.0m length with a spacing of 22.5 x 10 cm. The experiment was conducted in a red sandy loam soil with a neutral pH, low in organic carbon. Recommended agronomic and plant protection measures were adopted for the conduct of experiment. Twenty random plants were sampled for recording observations from each cross per replication and their mean values were used. The data were recorded for twenty three quantitative traits *viz.,* plant height, number of primary branches per plant, number of secondary branches per plant, SPAD chlorophyll meter reading, specific leaf area, specific leaf weight, leaf area index, transpiration rate, photosynthetic rate, stomatal conductance, water use efficiency, number of well-filled and mature pods per plant, shelling per cent, sound mature kernel per cent, 100-kernel weight, dry haulm weight per plant, harvest index, oil per cent, protein content, kernel yield per plant and pod yield per plant. Days to 50% flowering and days to maturity were recorded on plot basis. Genotypic and phenotypic correlation coefficients were calculated using the formulae suggested by Al-Jibouri *et al.,* (1958). Path coefficient analysis was carried out by using phenotypic and genotypic correlation coefficients as per the method suggested by Dewey and Lu (1959).

Table 1.Phenotypic (P) and genotypic (G) correlation coefficients among physiological, yield and yield component characters in F_1 generation of groundnut.

Character		Days to 50% flowering	Days to maturity	Plant height	No. of primary branches per plant	No. of secondary branches per plant	SPAD chlorophyll meter reading at 60 DAS	Specific leaf area at 60 DAS	Specific leaf weight at 60 DAS	Leaf area indexat 60 DAS	Transpira tion rate at 60 DAS	Photosyn thetic rate at 60 DAS	Stomatal conduct ance at 60 DAS	Water use efficiency at 60 DAS	Pod yield per plant
Days to 50% flowering	P	1.0000	0.4588*	0.1681	0.1069	-0.1367	0.0812	0.0673	-0.0027	-0.2514	0.4159*	0.3983*	0.1017	-0.1250	-0.1272
	G	1.0000	0.5216**	0.3043	0.2429	-0.1086	0.2049	0.1418	-0.0059	-0.3977*	0.8354**	0.8175**	0.1907	-0.2649	-0.3172
Days to maturity	P		1.0000	0.3160	0.2259	0.0320	-0.0523	0.0267	-0.0896	0.0330	0.1626	-0.0269	0.1174	-0.1862	0.1540
	G		1.0000	0.4727*	0.5006**	0.0860	-0.0739	-0.0448	-0.1597	0.0123	0.3670	-0.0582	0.3787*	-0.1977	0.2649
Plant height	P			1.0000	0.3867*	0.3485	0.0261	-0.0974	-0.0063	-0.2520	0.0805	-0.0336	0.0736	0.1516	0.1705
	G			1.0000	0.7252**	1.1099**	0.0908	-0.2873	-0.1591	-0.5428**	-0.0689	-0.1071	0.0493	0.4712*	0.6982**
No. of primary branches per plant	P				1.0000	0.5052**	0.0412	-0.1497	0.0850	-0.2312	0.1667	0.2090	0.0485	0.0569	0.2636
	G				1.0000	1.0889**	-0.2477	-0.9218**	0.1534	-0.7469**	0.1599	0.3818*	0.3060	0.4437*	0.6281**
No. of secondary branches per plant	P					1.0000	-0.0370	-0.0677	-0.0607	-0.0997	-0.1138	0.0940	0.0042	0.2112	0.1202
	G					1.0000	-0.4600*	-0.6994**	0.0061	-0.8095**	-0.2842	-0.0296	0.0189	0.8109**	0.3413
SPAD chlorophyll meter reading	P						1.0000	-0.0542	0.2163	-0.0491	0.1537	-0.1014	0.1005	0.1179	-0.0110
	G						1.0000	0.0965	0.6116**	0.0738	0.6694**	0.1280	0.4912**	0.1570	-0.0560
Specific leaf area	P							1.0000	-0.4451*	0.1410	-0.0298	-0.0422	-0.1747	-0.1179	0.0328
	G							1.0000	-0.7194**	0.8422**	-0.2259	-0.4210*	-0.0993	-0.0964	-0.3335
Specific leaf weight	P								1.0000	-0.1423	0.1901	0.0041	0.1006	0.0041	-0.0334
	G								1.0000	-0.6761**	0.5803**	0.4555*	0.5051**	-0.2917	-0.1248
Leaf area index	P									1.0000	-0.0139	-0.2007	0.0136	-0.0941	-0.0476
	G									1.0000	-0.0626	-0.6798**	0.2154	-0.2021	0.0675
Transpiration rate	P										1.0000	0.3803*	0.3536	-0.3769*	-0.0326
	G										1.0000	0.9217**	1.3419**	-0.6772**	0.2126
Photosynthetic rate	P											1.0000	0.2574	-0.0470	0.0527
	G											1.0000	-0.0022	-0.1352	-0.0344
Stomatal conductance	P												1.0000	-0.1379	0.0008
	G												1.0000	-0.5132**	0.6260**
Water use efficiency	P													1.0000	0.1523
	G													1.0000	0.3480
Pod yield per plant	P														1.0000
	G														1.0000

* Significant at 5% level ** Significant at 1% level

Table 1 . Contd…

Character		No. of well-filled and mature pods per plant	Shelling %	SMK %	100 kernel weight	Dry haulm weight per plant	Harvest index	Oil per cent	Protein per cent	Kernel yield per plant	Pod yield per plant
Days to 50% flowering	P	-0.3467	-0.0747	-0.2118	-0.2212	0.3220	0.2689	-0.2537	-0.1778	-0.1238	-0.1272
	G	-0.3731	-0.2293	-0.4347*	-0.4465*	0.5641**	0.4965**	-0.3511	-1.1004**	-0.2548	-0.3172
Days to maturity	P	-0.0931	-0.1193	-0.0513	-0.0404	0.2729	0.1628	-0.2532	0.0789	0.1199	0.1540
	G	-0.0829	-0.2132	-0.1892	-0.0094	0.4645*	0.3415	-0.3864*	0.1810	0.0608	0.2649
Plant height	P	0.0941	-0.1929	-0.1161	0.1351	0.3135	0.2678	-0.2987	-0.0373	0.1534	0.1705
	G	0.2528	-0.0099	-0.0226	-0.0691	0.5207**	0.3768*	-0.7560**	0.7988**	0.3687	0.6982**
No. of primary branches per plant	P	0.0402	-0.3115	-0.0554	0.2066	0.4241*	0.2577	-0.3013	-0.1496	0.2521	0.2636
	G	-0.0159	-0.3060	0.3389	-0.0700	0.8218**	0.6865**	-1.0351**	-0.1953	0.4385*	0.6281**
No. of secondary branches per plant	P	0.0972	-0.2799	0.1714	0.1664	0.3175	0.2461	-0.1512	-0.0286	0.0733	0.1202
	G	0.1985	-0.3118	-0.2952	-0.0935	0.3986*	0.5527**	-0.6801**	1.0835**	0.0320	0.3413
SPAD chlorophyll meter reading	P	-0.0202	-0.0113	0.1948	0.0190	0.1389	0.1348	0.0677	-0.0022	0.0020	-0.0110
	G	-0.0585	0.1066	0.5379**	-0.3676	0.1970	0.2539	0.0002	0.2165	-0.1134	-0.0560
Specific leaf area	P	0.0693	0.0384	0.0414	-0.0293	-0.2023	-0.1452	0.0570	0.0382	-0.0574	0.0328
	G	0.4658*	0.1100	-0.2960	-0.6651**	-0.7655**	-0.7774**	0.4802**	0.0331	-0.4088*	-0.3335
Specific leaf weight	P	-0.1072	-0.1377	-0.0217	-0.0229	0.2020	0.1409	-0.0517	-0.0255	0.0348	-0.0334
	G	-0.4746*	-0.1857	0.3966*	-0.2180	0.6341**	0.8119**	-0.4135*	-0.1408	0.0704	-0.1248
Leaf area index	P	0.0815	0.0670	0.1968	0.1206	-0.2369	-0.2829	-0.0181	0.1728	0.0398	-0.0476
	G	0.1133	0.0449	0.8287**	0.9640**	-0.5651**	-0.7767**	0.4940**	1.8656**	-0.2383	0.0675
Transpiration rate	P	-0.0846	-0.1975	0.0858	0.1321	0.2176	0.1130	-0.1938	-0.1341	0.0216	-0.0326
	G	-0.2511	-0.6065**	0.0675	-0.6404**	0.1756	-0.1059	-0.6670**	0.8806**	0.2168	0.2126
Photosynthetic rate	P	-0.0977	-0.1646	0.0123	0.1034	0.1862	0.1324	-0.0569	-0.2186	0.1078	0.0527
	G	-0.3590	-0.5927**	-0.0981	-0.4209*	0.2039	0.0170	-0.4117*	-1.6607**	-0.0619	-0.0344
Stomatal conductance	P	0.0077	-0.1117	0.1771	0.1613	0.0272	-0.0221	-0.1695	0.1296	0.0691	0.0008
	G	0.0786	-0.7126**	0.2892	0.0008	-0.0913	-0.5254**	-0.4240*	1.6723**	0.5395**	0.6260**
Water use efficiency	P	-0.0023	0.2431	-0.0087	0.0571	0.0348	0.0891	-0.0253	0.0577	0.0754	0.1523
	G	-0.0078	0.4088*	0.2172	0.1780	0.2492	0.3793*	-0.0136	0.7033**	0.2183	0.3480
No. of well-filled and mature pods per plant	P	1.0000	0.1543	0.2560	0.1388	-0.0563	-0.1294	-0.0569	0.0192	0.2812	0.3415
	G	1.0000	0.3627	0.7103**	0.3286	-0.1006	-0.2027	-0.1182	0.4306*	0.4288*	0.5813**
Shelling per cent	P		1.0000	0.0472	-0.0903	-0.0759	-0.0420	0.0242	0.1107	0.1354	0.0455
	G		1.0000	0.1063	0.7466**	-0.1072	-0.1486	0.2797	-0.1213	0.5590**	0.3601
Sound mature kernel per cent	P			1.0000	0.2109	-0.0863	-0.2254	-0.0487	0.0926	0.2100	0.2000
	G			1.0000	0.8611**	0.0949	-0.2761	0.1658	-0.0482	0.2306	0.2540
100- kernel weight	P				1.0000	0.0583	-0.0630	0.0319	0.1043	0.2099	0.2004
	G				1.0000	-0.3156	-0.7704**	-0.3777*	2.6992**	0.8425**	0.9383**
Dry haulm weight per plant	P					1.0000	0.8507**	-0.0737	-0.1992	0.0476	0.1015
	G					1.0000	0.8667**	-0.5712**	-0.7870**	0.2640	0.1997
Harvest index	P						1.0000	0.0290	-0.1444	-0.2134	-0.1544
	G						1.0000	-0.3267	-0.2085	-0.1351	-0.1625
Oil per cent	P							1.0000	-0.1487	-0.2387	-0.2241
	G							1.0000	0.4640*	-0.3950*	-0.5968**
Protein per cent	P								1.0000	0.0017	0.0389
	G								1.0000	-0.0993	0.0234
Kernel yield per plant	P									1.0000	0.7914**
	G									1.0000	1.1897**
Pod yield per plant	P										1.0000
	G										1.0000

* Significant at 5% level ** Significant at 1% level

RESULTS AND DISCUSSION

Pod yield per plant had significant positive association with plant height, number of well-filled and mature pods per plant, 100-kernel weight and kernel yield per plant in F_1s (Table 1). These characters can be considered as criteria for selection for higher yield, as these were mutually and directly associated with pod yield. Similar results were also reported by Jonah *et al.,* (2010) and Korat *et al*., (2010).

The characters, number of well-filled and mature pods per plant and 100- kernel weight recorded highly significant positive association with kernel yield per plant indicating the positive linear relationship of these characters with kernel yield. The results indicate that with the improvement in these characters improvement in pod yield can be achieved. Similar kind of positive significant association of kernel yield with mature pods per plant were also reported by Venkataravana *et al.,* (2000), Trivikrama Reddy (2003), Hemanth Kumar (2004) and Lakshmidevamma *et al.,* (2004) and Venkateswarlu (2007).

Days to 50 per cent flowering established a significant positive association with days to maturity and dry haulms yield per plant in generation and its relationship with plant height was non significant positive association. The characters SCMR and specific leaf area established a positive non significant association with days to 50 per cent flowering respectively. Days to maturity had significant positive association with number of primary branches per plant, plant height and dry haulms yield per plant. Similar results were reported by Korat *et al*., (2010). Plant height exhibited significant positive association with number of secondary branches per plant. The characters number of primary branches per plant, dry haulms yield per plant and harvest index with plant height established a significant positive association. Non significant and positive association of number of primary branches per plant was observed with number of secondary branches per plant. The increased number of primary branches led to over growth as photosynthetic energy which is likely to be utilized for the development of pods. The character number of secondary branches per plant exhibited positive and significant association with dry haulms yield per plant.

SPAD chlorophyll meter reading was found to be negatively associated with SLA in F_1 generation. Nageswara Rao *et al.,* (2001) reported positive relation between SCMR and SLN and negative relation between SCMR and SLA in groundnut. Samdur *et al.,* (2000) demonstrated a strong positive association between SCMR and chlorophyll content in groundnut and concluded that SCMR could be used for rapid and *in situ* screening genotypes for drought tolerance. SCMR also exhibited a positive non significant relationship with harvest index. Painawadee *et al.,* (2009) and Arunyanark *et al*., (2010) reported that SCMR had negative association with SLA.

SLA at 60 DAS showed negative non significant association. Songsri *et al.,* (2008) reported that SLA had strong and negative relation with SCMR. SPAD chlorophyll meter reading, which is easy to measure, is potentially useful as a selection trait for drought tolerance. Leaf area index at 60 DAS showed significant and positive association with protein per cent. The character transpiration rate displayed significant positive association with photosynthetic rate. The characters SMK and dry haulms yield per plant with transpiration rate established a positive non significant association.

The association between stomatal conductance and protein per cent was significant and positive. It had significant negative association with water use efficiency in F_1s. Water use efficiency showed non significant positive association with pod yield per plant. Number of well-filled and mature pods per plant had significant positive association with kernel yield per plant and pod yield per plant. Similar resulted were reported by Makhan lal *et al*. (2003). Shelling per cent established significant positive association with kernel yield per plant in F_1 generation. These results were confirmed with the findings of Islam and Rasul (1998) for positive association of shelling with kernel yield. Sound mature kernel per cent recorded significant relation in F_1 generation. These results were confirmed with the findings of Sumathi and Muralidharan (2009).

The character 100-kernel weight displayed significant and positive association with kernel yield per plant and pod yield per plant. It established non significant positive association with protein per cent in parents and significant positive association. On contrary negative correlation of 100-kernel weight with protein content was reported by Johar Singh and Mohinder Singh (2001). Dry haulms yield per plant had significant positive association with harvest index and non significant positive association. The relationship between oil per cent and protein per cent was negative non significant in parents but significant positive association. Earlier

Table 2. Path coefficients for pod yield and its components in F_1 generation of groundnut

Character		Days to 50% flowering	Days to maturity	Plant height	No. of primary branches per plant	No. of secondary branches per plant	SPAD chlorophyll meter reading at 60 DAS	Specific leaf area at 60 DAS	Specific leaf weight at 60 DAS	Leaf area index at 60 DAS	Transpiration rate at 60 DAS
Days to 50% flowering	P	**-0.1250**	0.0523	-0.0088	-0.0028	0.0092	-0.0013	0.0071	0.0001	0.0371	0.0026
	G	**0.2206**	-0.3068	-0.2836	0.3698	-0.0116	0.0854	-0.0548	0.0060	0.1242	0.3479
Days to maturity	P	-0.0573	**0.1139**	-0.0164	-0.0060	-0.0022	0.0008	0.0028	0.0025	-0.0049	0.0010
	G	0.1151	**-0.5881**	-0.4406	0.7621	0.0092	-0.0308	0.0173	0.1629	-0.0038	0.1528
Plant height	P	-0.0210	0.0360	**-0.0521**	-0.0102	-0.0235	-0.0004	-0.0103	0.0002	0.0371	0.0005
	G	0.0671	-0.2780	**-0.9319**	1.1039	0.1184	0.0379	0.1110	0.1622	0.1695	-0.0287
No. of primary branches per plant	P	-0.0134	0.0257	-0.0201	**-0.0263**	-0.0340	-0.0007	-0.0158	-0.0023	0.0341	0.0011
	G	0.0536	-0.2944	-0.6758	**1.5223**	0.1161	-0.1033	0.3560	-0.1564	0.2332	0.0666
No. of secondary branches per plant	P	0.0171	0.0036	-0.0181	-0.0133	**-0.0673**	0.0006	-0.0072	0.0017	0.0147	-0.0007
	G	-0.0240	-0.0506	-1.0343	1.6576	**0.1067**	-0.1918	0.2702	-0.0063	0.2527	-0.1184
SPAD chlorophyll meter reading	P	-0.0101	-0.0060	-0.0014	-0.0011	0.0025	**-0.0162**	-0.0057	-0.0060	0.0072	0.0010
	G	0.0452	0.0435	-0.0847	-0.3770	-0.0491	**0.4170**	-0.0373	-0.6236	-0.0230	0.2788
Specific leaf area	P	-0.0084	0.0030	0.0051	0.0039	0.0046	0.0009	**0.1057**	0.0198	-0.0208	-0.0002
	G	0.0313	0.0264	0.2677	-1.4033	-0.0746	0.0403	**-0.3862**	0.4538	-0.2629	-0.0941
Specific leaf weight	P	0.0003	-0.0102	0.0003	-0.0022	0.0041	-0.0035	-0.0761	**-0.0276**	0.0210	0.0012
	G	-0.0013	0.0940	0.1483	0.2335	0.0007	0.2550	0.1719	**-1.0197**	0.2111	0.2417
Leaf area index	P	0.0314	0.0038	0.0131	0.0061	0.0067	0.0008	0.0149	0.0039	**-0.1474**	-0.0001
	G	-0.0877	-0.0072	0.5058	-1.1370	-0.0864	0.0308	-0.3253	0.6893	**-0.3122**	-0.0261
Transpiration rate	P	-0.0520	0.0185	-0.0042	-0.0044	0.0077	-0.0025	-0.0031	-0.0052	0.0020	**0.0064**
	G	0.1843	-0.2159	0.0642	0.2434	-0.0303	0.2791	0.0872	-0.5917	0.0195	**0.4164**
Photosynthetic rate	P	-0.0498	-0.0031	0.0017	-0.0055	-0.0063	0.0016	-0.0045	-0.0001	0.0296	0.0024
	G	0.1804	0.0342	0.0998	0.5813	-0.0032	0.0534	0.1626	-0.4644	0.2122	0.3838
Stomatal conductance	P	-0.0127	0.0134	-0.0038	-0.0013	-0.0003	-0.0016	-0.0185	-0.0028	-0.0020	0.0023
	G	0.0421	-0.2227	-0.0460	0.4658	0.0020	0.2048	0.0384	-0.5151	-0.0672	0.5588
Water use efficiency	P	0.0156	-0.0212	-0.0079	-0.0015	-0.0142	-0.0019	-0.0125	-0.0001	0.0139	-0.0024
	G	-0.0584	0.1163	-0.4391	0.6755	0.0865	0.0655	0.0372	0.2974	0.0631	-0.2820
No. of well-filled and mature pods per plant	P	0.0433	-0.0106	-0.0049	-0.0011	-0.0065	0.0003	0.0073	0.0030	-0.0120	-0.0005
	G	-0.0823	0.0488	-0.2356	-0.0242	0.0212	-0.0244	-0.1799	0.4840	-0.0354	-0.1046
Shelling per cent	P	0.0093	-0.0136	0.0100	0.0082	0.0189	0.0002	0.0041	0.0038	-0.0099	-0.0013
	G	-0.0506	0.1254	0.0092	-0.4658	-0.0333	0.0445	-0.0425	0.1894	-0.0140	-0.2526
Sound mature kernelper cent	P	0.0265	-0.0058	0.0060	0.0015	-0.0115	-0.0031	0.0044	0.0006	-0.0290	0.0005
	G	-0.0959	0.1113	0.0211	0.5159	-0.0315	0.2243	0.1143	-0.4044	-0.2587	0.0281
100- kernel weight	P	0.0277	-0.0046	-0.0070	-0.0054	-0.0112	-0.0003	-0.0031	0.0006	-0.0178	0.0008
	G	-0.0985	0.0056	0.0644	-0.1065	-0.0100	-0.1533	0.2569	0.2223	-0.3010	-0.2667
Dry haulm weight per plant	P	-0.0402	0.0311	-0.0163	-0.0112	-0.0214	-0.0022	-0.0214	-0.0056	0.0349	0.0014
	G	0.1245	-0.2732	-0.4852	1.2510	0.0425	0.0822	0.2957	-0.6465	0.1764	0.0731
Harvest index	P	-0.0336	0.0186	-0.0139	-0.0068	-0.0166	-0.0022	-0.0154	-0.0039	0.0417	0.0007
	G	0.1095	-0.2008	-0.3512	1.0451	0.0590	0.1059	0.3003	-0.8278	0.2425	-0.0441
Oil per cent	P	0.0317	-0.0288	0.0156	0.0079	0.0102	-0.0011	0.0060	0.0014	0.0027	-0.0012
	G	-0.0775	0.2272	0.7046	-1.5757	-0.0725	0.0001	-0.1855	0.4216	-0.1542	-0.2778
Protein per cent	P	0.0222	0.0090	0.0019	0.0039	0.0019	0.0000	0.0040	0.0007	-0.0255	-0.0009
	G	-0.2428	-0.1065	-0.7444	-0.2973	0.1156	0.0903	-0.0128	0.1436	-0.5824	0.3667
Kernel yield per plant	P	0.0155	0.0137	-0.0080	-0.0066	-0.0049	0.0000	-0.0061	-0.0010	-0.0059	0.0001
	G	-0.0562	-0.0358	-0.3436	0.6676	0.0034	-0.0473	0.1579	-0.0718	0.0744	0.0903
Phenotypic Residual Effect			0.4864								
Genotypic Residual Effect			0.1660								

* Significant at 5% level ** Significant at 1% level Diagonal values (Bold) : Direct effects

Table 2 Contd….

	Photosynthetic rate at 60 DAS	Stomatal conductance at 60 DAS	Water use efficiency at 60 DAS	Correlation with pod yield per plant	No. of well-filled and mature pods per plant	Shelling %	SMK %	100 kernel weight	Dry haulm weight per plant	Harvest index	Oil per cent	Protein per cent	Kernel yield per plant	Correlation with pod yield per plant
P	0.0014	-0.0047	-0.0213	-0.1272	-0.0460	0.0096	-0.0015	-0.0001	0.1285	-0.0865	0.0142	-0.0094	-0.0819	-0.1272
G	-1.0541	0.1212	0.0372	-0.3172	0.0913	-0.2929	-0.0546	0.1975	0.0909	-0.3923	0.2457	0.1084	0.0871	-0.3172
P	-0.0001	-0.0054	-0.0317	0.154	-0.0124	0.0153	-0.0004	0.0000	0.1089	-0.0524	0.0142	0.0042	0.0794	0.154
G	0.0751	0.2408	0.0278	0.2649	0.0203	-0.2722	-0.0237	0.0042	0.0748	-0.2698	0.2704	-0.0178	-0.0208	0.2649
P	-0.0001	-0.0034	0.0258	0.1705	0.0125	0.0248	-0.0008	0.0001	0.1251	-0.0862	0.0168	-0.0020	0.1016	0.1705
G	0.1381	0.0314	-0.0662	0.6982**	-0.0619	-0.0127	-0.0028	0.0306	0.0839	-0.2977	0.5290	-0.0787	-0.1261	0.6982**
P	0.0007	-0.0022	0.0097	0.2636	0.0053	0.0400	-0.0004	0.0001	0.1693	-0.0829	0.0169	-0.0079	0.1669	0.2636
G	-0.4923	0.1945	-0.0624	0.6281**	0.0039	-0.3908	0.0425	0.0310	0.1324	-0.5424	0.7243	0.0193	-0.1499	0.6281**
P	0.0003	-0.0002	0.0360	0.1202	0.0129	0.0359	0.0012	0.0001	0.1267	-0.0792	0.0085	-0.0015	0.0485	0.1202
G	0.0382	0.0120	-0.1140	0.3413	-0.0486	-0.3982	-0.0371	0.0414	0.0642	-0.4367	0.4759	-0.1068	-0.0109	0.3413
P	-0.0004	-0.0046	0.0201	-0.011	-0.0027	0.0015	0.0014	0.0000	0.0554	-0.0434	-0.0038	-0.0001	0.0013	-0.011
G	-0.1651	0.3122	-0.0221	-0.056	0.0143	0.1362	0.0675	0.1627	0.0317	-0.2006	-0.0001	-0.0213	0.0388	-0.056
P	-0.0001	0.0080	-0.0201	0.0328	0.0092	-0.0049	0.0003	0.0000	-0.0807	0.0467	-0.0032	0.0020	-0.0380	0.0328
G	0.5428	-0.0631	0.0136	-0.3335	-0.1140	0.1405	-0.0371	0.2942	-0.1233	0.6142	-0.3360	-0.0033	0.1398	-0.3335
P	0.0000	-0.0046	0.0007	-0.0334	-0.0142	0.0177	-0.0002	0.0000	0.0806	-0.0453	0.0029	-0.0013	0.0230	-0.0334
G	-0.5872	0.3211	0.0410	-0.1248	0.1162	-0.2372	0.0498	0.0965	0.1022	-0.6414	0.2894	0.0139	-0.0241	-0.1248
P	-0.0007	-0.0006	-0.0160	-0.0476	0.0108	-0.0086	0.0014	0.0000	-0.0945	0.0910	0.0010	0.0091	0.0263	-0.0476
G	0.8764	0.1369	0.0284	0.0675	-0.0277	0.0573	0.1040	-0.4265	-0.0910	0.6136	-0.3457	-0.1839	0.0815	0.0675
P	0.0013	-0.0163	-0.0642	-0.0326	-0.0112	0.0254	0.0006	0.0000	0.0868	-0.0363	0.0109	-0.0071	0.0143	-0.0326
G	-1.1883	0.8530	0.0952	0.2126	0.0615	-0.7746	0.0085	0.2833	0.0283	0.0837	0.4667	-0.0868	-0.0741	0.2126
P	**0.0035**	-0.0118	-0.0080	0.0527	-0.0130	0.0211	0.0001	0.0000	0.0743	-0.0426	0.0032	-0.0116	0.0714	0.0527
G	**-1.2893**	-0.0014	0.0190	-0.0344	0.0879	-0.7569	-0.0123	0.1862	0.0328	-0.0134	0.2881	0.1637	0.0212	-0.0344
P	0.0009	**-0.0460**	-0.0235	0.0008	0.0010	0.0143	0.0012	0.0001	0.0108	0.0071	0.0095	0.0069	0.0458	0.0008
G	0.0029	**0.6357**	0.0721	0.6260**	-0.0192	-0.9101	0.0363	-0.0004	-0.0147	0.4151	0.2967	-0.1648	-0.1845	0.6260**
P	-0.0002	0.0063	**0.1703**	0.1523	-0.0003	-0.0312	-0.0001	0.0000	0.0139	-0.0287	0.0014	0.0031	0.0499	0.1523
G	0.1743	-0.3262	**-0.1406**	0.348	0.0019	0.5221	0.0273	-0.0787	0.0401	-0.2997	0.0095	-0.0693	-0.0746	0.348
P	-0.0003	-0.0004	-0.0004	0.3415	**0.1328**	-0.0198	0.0018	0.0001	-0.0225	0.0416	0.0032	0.0010	0.1862	0.3415
G	0.4628	0.0500	0.0011	0.5813**	**-0.2448**	0.4632	0.0892	-0.1454	-0.0162	0.1601	0.0827	-0.0424	-0.1466	0.5813**
P	-0.0006	0.0051	0.0414	0.0455	0.0205	**-0.1283**	0.0003	0.0000	-0.0303	0.0135	-0.0014	0.0059	0.0896	0.0455
G	0.7642	-0.4530	-0.0575	0.3601	-0.0888	**1.2772**	0.0133	-0.3303	-0.0173	0.1174	-0.1957	0.0120	-0.1911	0.3601
P	0.0000	-0.0081	-0.0015	0.2	0.0340	-0.0061	**0.0070**	0.0001	-0.0345	0.0725	0.0027	0.0049	0.1390	0.20
G	0.1264	0.1838	-0.0305	0.254	-0.1739	0.1358	**0.1255**	-0.3810	0.0153	0.2182	-0.1160	0.0048	-0.0788	0.254
P	0.0004	-0.0074	0.0097	0.2004	0.0184	0.0116	0.0015	**0.0004**	0.0233	0.0203	-0.0018	0.0055	0.1389	0.2004
G	0.5427	0.0005	-0.0250	0.9383**	-0.0804	0.9536	0.1081	**-0.4424**	-0.0508	0.6087	0.2643	-0.2660	-0.2881	0.9383**
P	0.0006	-0.0012	0.0059	0.1015	-0.0075	0.0097	-0.0006	0.0000	**0.3991**	-0.2788	0.0041	-0.0105	0.0315	0.1015
G	-0.2629	-0.0580	-0.0350	0.1997	0.0246	-0.1369	0.0119	0.1396	**0.1611**	-0.6722	0.3997	0.0776	-0.0903	0.1997
P	0.0005	0.0010	0.0152	-0.1544	-0.0172	0.0054	-0.0016	0.0000	0.3460	**-0.3217**	-0.0016	-0.0076	-0.1412	-0.1544
G	-0.0219	-0.3340	-0.0533	-0.1625	0.0496	-0.1897	-0.0347	0.3408	0.1371	**-0.7901**	0.2286	0.0206	0.0462	-0.1625
P	-0.0002	0.0078	-0.0043	-0.2241	-0.0076	-0.0031	-0.0003	0.0000	-0.0294	-0.0093	**-0.0561**	-0.0079	-0.1580	-0.2241
G	0.5308	-0.2696	0.0019	-0.5968**	0.0289	0.3573	0.0208	0.1671	-0.0920	0.2581	**-0.6998**	-0.0457	0.1350	-0.5968**
P	-0.0008	-0.0060	0.0098	0.0389	0.0025	-0.0142	0.0006	0.0000	-0.0795	0.0464	0.0083	**0.0529**	0.0011	0.0389
G	2.1412	1.0631	-0.0989	0.0234	-0.1054	-0.1550	-0.0061	-1.1942	-0.1268	0.1648	-0.3247	**-0.0986**	0.0339	0.0234
P	0.0004	-0.0032	0.0128	0.7914**	0.0373	-0.0174	0.0015	0.0001	0.0190	0.0686	0.0134	0.0001	**0.6620**	0.7914**
G	0.0798	0.3430	-0.0307	1.1897**	-0.1050	0.7140	0.0289	-0.3728	0.0425	0.1067	0.2764	0.0098	**-0.3419**	1.1897**
Phenotypic Residual Effect						0.4864								
Genotypic Residual Effect						0.1660								

* Significant at 5% level ** Significant at 1% level Diagonal values (Bold) : Direct effects

Parmar *et al.*, (2000) reported that oil and protein content showed a strong negative relationship indicating that selection for low oil content should result in higher protein content. pod yield per plant established a non significant positive association in F_1s generation.

From the foregoing discussion during, it is evident that pod yield per plant was closely associated with plant height, number of well-filled and mature pods per plant and kernel yield per plant. The significant association of physiological and yield attributes among themselves revealed significant positive association of photosynthetic rate with stomatal conductance and water use efficiency. SCMR had significant negative association with specific leaf area. Positive significant association of number of primary branches per plant with number of secondary branches per plant, stomatal conductance and 100- kernel weight, specific leaf area with protein per cent, transpiration rate with photosynthetic rate, stomatal conductance with protein per cent, shelling per cent with SMK per cent and oil per cent, 100- kernel weight with kernel yield per plant and pod yield per plant, dry haulms yield per plant with harvest index indicate that selection for these traits might be rewarding in improvement of tolerance to drought besides pod yield in groundnut.

Path co-efficient analysis

Pod yield is a complex dependent character and is contributed by several components. Correlation studies simply measures the association of yield and yield attributes and does not give the actual dependence of yield on the correlated characters. Path coefficient analysis is an effective method to determine the direct and indirect causes of associations and also permits to examine the specific forces acting to produce to a given correlation. Majority of the reports of path analysis are based on variability existing between homozygous cultivars. It is necessary to emphasize that inferences derived from these will be meaningful only when this study is based on individual plant observations in a segregating generation. Hence, an attempt was made to study the direct and indirect effects of characters on pod yield through path coefficient analysis of twenty eight cross combinations in groundnut and presented in Table 2.

The results of path analysis revealed that kernel yield per plant had maximum positive direct effect on pod yield per plant in F_1s indicating kernel yield is the important yield contributing character. Mathews *et al.,* (2000) reported maximum positive direct effect of kernel yield on pod yield in groundnut. A perusal of path coefficients in F_1 generation, revealed the moderate direct positive effect of number of well-filled and mature pods per plant on pod yield in groundnut. The high direct effect of pods per plant was appeared to be the main factor for its strong positive correlation with pod yield. Hence, a direct selection for this trait would be effective. These findings are in agreement with the results of Venkataravana *et al.,* (2000), Lakshmidevamma (2004), Parameswarappa *et al.,* (2008) and Vaithiyalingan *et al.,* (2010).

Besides their positive and high direct effects, the character number of well-filled and mature pods per plant, sound mature kernel per cent and protein per cent exerted their high positive direct effects on pod yield in crosses. Earlier Korat *et al.* (2010) reported that harvest index and 100- kernel weight were identified as the most important yield contributing characters. Similar findings were also reported by Azad and Hamid (2000), Siddiquet *et al.,* (2006), Parameswarappa *et al.,* (2008) and Vaithiyalingan *et al.,* (2010).

The direct positive effect towards pod yield was obtained and photosynthetic rate specific leaf weight, dry haulms yield and leaf area index, the lesser direct effect of number of well-filled and mature pods per plant and kernel yield per plant to that of their correlation coefficients in crosses were chiefly due to their indirect contribution via kernel yield per plant and number of well-filled and mature pods per plant, respectively.

The characters, number of well-filled and mature pods per plant, sound mature kernel per cent, oil per cent and protein per cent exerted their high positive indirect effects through kernel yield per plant. These results were confirmed with the findings of Gomes *et al.,* (2005) and Giri *et al*., (2009). The other characters which contributed their positive indirect effects on kernel yield through *viz*., photosynthetic rate dry haulms yield per plant days to 50 per cent flowering, days to maturity, transpiration rate and water use efficiency. From the above discussion on path coefficient analysis it can be concluded that, kernel yield per plant and number of well-filled and mature pods per plant had maximum positive direct effect on pod yield per plant indicating that these traits are the important yield contributing characters.

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