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Studies on Variability, Character Association and Path Analysis on Groundnut (*Arachis hypogaea* L.)

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ABSTRACT

In the present investigation 18 Spanish bunch groundnut genotypes were used for variability, character association and path analysis studies in 19 plant characters. In general higher GCV and heritability estimates coupled with high genetic advance as per cent of mean recorded for LLS severity, reducing sugar and non-reducing sugar indicated lesser influence of environment in expression of these characters and these characters are controlled by additive gene effect, hence, amenable for simple selection. Pod yield per plant exhibited positive significant association with number of pods per plant, total sugar, kernel yield, non reducing sugar, test weight, SCMR, harvest index, oil content and shelling per cent, whereas, LLS severity, reducing sugar, stomata frequency and size showed negative significant association. Total sugar, kernel yield, stomata length, LLS severity, test weight, SCMR, days to maturity and oil content exerted the positive direct effect on pod yield, whereas, non-reducing sugar, stomata frequency, shelling per cent and harvest index had maximum indirect direct effects on pod yield per plant. Thus, due emphasis should be placed on these characters while selecting genotypes for high yield with LLS tolerance in groundnut

Key words: *Genetic variability, Heritability, Character association and Path analysis*

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important annual legume oilseed crop grown in tropical and sub-tropical regions of the world. It is a valuable source of dietary protein, oil and fodder for livestock. Its kernel contains 48-50% oil and 26-28% protein and a rich source of dietary fibre, minerals and vitamins. The low productivity and production of groundnut is mainly due to several biotic and abiotic stresses affecting the crop at various growth stages. Among the biotic stresses, late leaf spot (*Phaeoisariopsis personata* [(Berk. and Curt.) Deighton]) and rust (*Puccinia arachidicola* Speg.) are most important. These two diseases often occur together and causes up to 50-70% of yield losses in the crop[29]. Use of fungicides to control leaf spots usually increases production costs by 10%.

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Therefore, development of cultivars resistant/tolerant to these diseases could be effective in reducing the production costs and the detrimental effects of chemicals on our ecosystem and improving quality production. Genetic variability is the basic requirement for crop improvement as this provides wider scope for selection. Thus, effectiveness of selection is dependent upon the nature, extent and magnitude of genetic variability present in the population and the extent to which it is heritable. Understanding the relationship between yield and its components is of the paramount importance for making the best use of the relationships in selection. The data obtained from correlation coefficient can be augmented by path analysis. Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects. Hence, in present investigation an attempt was made to assess the variability of important pod attributes and LLS disease resistance components along with the indices of variability *i.e.* genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in broad sense (h2 bs), genetic advance (Gs) and genetic advance as percentage of mean (GAM), the magnitude of relationship of individual yield components on yield, interrelationships among themselves and to measure their relative importance in the different genotypes of groundnut.

MATERIAL AND METHODS

The field experiment was carried out in randomized block design with three replications at Oilseed Research Station, Latur (MS) during *Kharif*, 2017. The experimental material comprised of 18 groundnut genotypes including three checks *viz.*, JL-24, LGN- 1 and LGN -123. The sowing was carried out by dibbling at the spacing of 30 x 10 cm between the rows and plant, respectively. The data was collected on five randomly chosen plants from each treatment and observations were recorded on pod yield plant per plant (g), number of pod plant per plant, kernel yield plant per plant(g), days to maturity, shelling per cent, test weight (g), harvest index (%), oil content (%), LLS disease severity (%), stomata frequency, stomata size (µm), SPAD chlorophyll meter reading, reducing sugar (mg/ g), non-reducing sugar (mg/ g) and total sugar(mg /g). Late leaf spot severity was scored on the 1-9 point scale as described by Subrahmanyam *et al.*[29] and then the score was transformed to percentage using arc-sine arc-sine transformation formula. Analysis of variance was carried out as per the method suggested by Panse and Sukhatme[24]. Phenotypic and genotypic coefficients of variations were computed as per Burton[4], heritability (broad sense) and genetic advance as followed as per Allard[1]. The genotypic and phenotypic coefficients of correlations were calculated using the method given by Johnson *et al.*[12]. Path coefficient analysis was carried out by using phenotypic and genotypic correlations coefficients as per the method suggested by Dewey and Lu[6].

RESULTS AND DISCUSSION

In the present study the analysis of variance for 19 characters revealed that significant differences were observed for all the characters. The variations of different traits under this study revealed that the phenotypic coefficient of variations (PCV) were higher than genotypic coefficient of variations (GCV) for all the characters studied indicating the role of environmental variance in the total variance (Table 1). Lesser differences were observed between PCV and GCV in all cases indicated greater role of genetic components and less influence by environment. Similar observations were also reported by Vasanthi *et al.*,[32] and Ashish *et al.*,[2]. Higher GCV estimates were observed for LLS severity, reducing sugar and non-reducing sugar. Hence, these characters can be relied upon and simple selection can be practiced for further improvement. These findings are in accordance with the earlier reports of Dolma *et al.*,[7], Padmaja *et al.*,[23] and Ashish *et al.*,[2] for LLS severity; Chari[5] for non-reducing sugar, Giri *et al.*,[8] and Sawargaonkar *et al.*,[27] for reducing sugar and LLS severity; Kahate and Toprope[15] for LLS disease severity, reducing sugar and non- reducing sugar. Moderate GCV were recorded for stomata breadth, total sugar, stomata length, number of pod per plant, test weight kernel yield and pod yield per plant. The results are in accordance with Vasanthi *et al.*,[32] and Kumar *et al.*,[16] for test weight and kernel yield; Rao *et al.*,[26] for number of pods per plant, kernel yield and pod yield; Shukla and Rai[30] for kernel yield and pod yield. The lowest GCV values were recorded for oil content, shelling per cent, days to maturity, stomata frequency, harvest index and SCMR. The similar estimates were recorded for shelling per cent and oil content by Wani *et al.*[33] and for stomatal frequency per mm^2 by Kahate and Toprope[15]

High heritability coupled with high genetic advance as per cent of mean recorded for LLS severity, reducing sugar and non-reducing sugar indicated lesser influence of environment in expression of these characters and these characters are controlled by additive gene effect, hence, amenable for simple selection. These results are in accordance with earlier reports of Vasanthi *et al.*,[32], Padmaja *et al.*,[23] and Ashish *et al.*,[2] for LLS severity; Giri *et al.*,[8] and Sawargaonkar *et al.*, [27] for LLS severity and reducing sugar; Kahate and Toprope[15] for LLS severity, reducing sugar and non- reducing. High to moderate heritability coupled with moderate genetic advance as per cent of mean has been noticed in stomata breadth, total sugar, test weight, SCMR, stomata length, kernel yield, pod yield and number of pods per plant. Similar result found by Nindini *et al.*,[22] for pod yield and kernel yield; Patil *et al.*,[25] for test wt. and kernel wt; Kahate *et al.*,[14] for test wt., stomatal length and stomatal breadth. High to moderate heritability and low genetic advance as per cent of mean was noticed for stomata frequency, oil content, and days to maturity and shelling indicated the influence of non-additive gene action. This suggests limited scope for further improvement of these characters. The results are in accordance with earlier work of Sunneta *et al.*,[31] for oil content and Kahate and Toprope[15] for stomata frequency and oil content.

In the present study, genotypic correlations were higher than phenotypic correlations for most of the characters. These indicate that the strong inherent association between the characters governed largely by genetic causes and reduced by environmental forces. The environment and genotype x environment interaction played a major role in determining these associations between the characters. The results pertaining to correlation studies are presented in table 2. The pod yield per plant exhibited highest, positive and significant association with number of pod per plant followed by total sugar, kernel yield, non-reducing sugar, test weight, SCMR, harvest index, oil content and shelling per cent. The similar kinds of associations earlier reported by Sharma and Dashora[28] for number of pods per plant and kernel yield, Gouda Patil *et al.*,[10] for number of pods per plant and shelling per cent, Azad and Hamid[3] and Rao *et al.*,[26] for number of pods per plant, kernel yield and test weight, Kadam *et al.*,[13] for number of pods per plant, harvest index, test weight and oil content, Kahate *et al.*,[14] for kernel yield, harvest index, non- reducing sugar and test weight and John and Reddy[11] for number of pod per plant , kernel yield per plant, test weight and shelling per cent.

The pod yield also exhibited negative and significant association with stomata frequency, stomata size (length and breadth), LLS severity and reducing sugar.The similar kind of findings were reported by Gopal *et al.*[9] for LLS severity, Giri *et al.*,[8] for LLS severity and reducing sugar, Kahate *et al.*,[14] for stomata size, stomata frequency, LLS disease severity and reducing sugar.

The positive and highly significant interrelationships were observed among yield contributing characters like number of pod per plant, kernel yield, shelling and test weight and morpho-biochemical traits like LLS severity, reducing sugar, stomata frequency and size. The results are in accordance with earlier reports of Lakshimidevamma *et al.*,[19] for kernel yield with test wt., Mahalakshmi *et al.*,[21] for kernel yield with test wt. and shelling; Kaur *et al.*,[17] for LLS severity with stomatal frequency; Li Dun[20] for LLS severity with reducing sugar. Kahate *et al.*,[14] for kernel yield with harvest index, non-reducing sugar and test wt.

The interrelationships were also negative and highly significant among yield contributing characters like number of pods per plant, kernel yield, test weight with morpho-biochemical traits like LLS severity, reducing sugar, stomata frequency and size. The similar result reported by Giri *et al.*,[8] and Kahate *et al.*,[14].

The path co-efficient studies (Table 3) indicated that total sugar, kernel yield , LLS severity , test weight , SCMR , days to maturity , stomata length and oil content exerted positive direct effect on pod yield. Hence, a direct selection criterion should be followed for these traits to improve the pod yield. Similar results were earlier reported by Giri *et al*.,[8] for kernel yield per plant , Khan *et al.*,[18] for test weight , *Zaman et al.*,[34] for days to maturity , Azad and Hamid[3] for kernel yield and test weight and Kadam *et al.*,[13] for oil content.

Negative direct effects on pod yield were also exhibited by some characters *viz.*, non-reducing sugar, stomatal frequency, shelling, harvest index and reducing sugar. The similar kinds of results earlier reported by Kahate *et al.*,[14] for stomata frequency and shelling and Lakshmidevamma *et al.*,[19] for shelling percent.

Thus for development high yielding disease resistance varieties in groundnut due emphasis should be given to LLS severity, reducing sugar, non reducing sugar, kernel yield plant^{-1}, harvest index, stomata size and frequency. All these characters had high GCV and PVC and heritability. Positive association of pod yield with number of pod per plant followed by total sugar, kernel yield, non-reducing sugar, test weight, SCMR, harvest index, oil content and shelling per cent and negative and significant association with stomata frequency, stomata size (length and breadth), LLS severity and reducing sugar indicated that these characters can be improved through direct selection.

Table 1: Estimates of variability, heritability and genetic advance in Groundnut

Sr. No.	Characters	Range	Mean	GCV (%)	PCV (%)	h^2(%) (Broad sense)	Genetic advance	GA as percent of mean
1	No. of pod plant per plan (g)	14.40-24.80	20.85	13.15	14.87	78.1	4.99	23.94
2	Kernel yield plant per plant(g)	8.16-13.95	11.53	12.22	15.89	59.1	2.23	19.35
3	Harvest index (%)	33.47-47.62	39.02	7.33	13.00	31.8	3.32	8.51
4	Days to maturity	93.66-110.00	99.46	3.85	4.01	91.9	7.56	7.60
5	Shelling (%)	60.67-69.33	65.52	3.49	4.07	73.6	4.05	6.18
6	LLS severity (%)	2.33-63.33	21.75	79.04	79.23	99.5	35.34	162.44
7	Test weight (g)	35.31-58.24	47.00	12.32	12.40	98.7	11.85	25.22
8	SCMR	33.23-48.40	44.38	8.63	9.19	88.1	7.41	16.69
9	Non reducing sugar (mg/ g)	6.10-14.40	10.40	29.56	29.81	98.4	6.28	60.41
10	Reducing sugar (mg/ g)	0.63-3.80	1.61	50.06	50.32	98.9	1.65	102.58
11	Total sugar(mg /)	8.80-15.03	12.01	18.94	19.14	97.9	4.64	38.62
12	Oil content (%)	46.90-48.00	47.42	0.80	0.92	74.7	0.67	1.42
13	Stomata frequency (Adaxial)	110.46-126.80	117.78	3.88	4.06	91.6	9.02	7.66
14	Stomata frequency (Abaxial)	109.20-125.26	116.30	3.95	4.09	93.1	9.14	7.86
15	Stomata length (μm) (Adaxial)	13.87-21.55	17.92	11.07	11.67	89.9	3.87	21.63
16	Stomata length (μm) (Abaxial)	11.39-21.25	16.92	14.13	14.46	95.5	4.81	28.45
17	Stomata breadth (μm) (Adaxial)	5.88-13.20	10.42	16.76	18.02	86.5	3.34	32.11
18	Stomata breadth (μm) (Abaxial)	5.42-12.14	9.39	20.85	21.68	92.5	3.88	41.31
19	Pod yield plant per plant (g)	13.44-20.56	17.57	10.69	14.36	55.4	2.88	16.39

Table 2: Genotypic (G) and phenotypic (P) coefficients among yield, yield contributing and morpho-biochemical characters in groundnut

Characters		KY	HI	DM	SH	LLS Severity	TW	SCMR	N.R. sugar	R. Sugar	Total sugar	Oil content	Stomata frequency		Stomata length		Stomata breath		PY
													Adaxial	abaxial	Adaxial	abaxial	Adaxial	abaxial	
No. of pod plant per plan (g)	G P	0.9352** 0.8968**	-0.0461 0.2538	-0.1264 -0.0880	0.2921* 0.2670	-0.9468** -0.8624**	0.9745** 0.8999**	0.6583** 0.5402**	0.9821** 0.9076**	-0.9819** -0.7555**	0.9779** 0.9053**	0.3504** 0.2768*	-0.9812** -0.9447**	-0.9637** -0.9308**	-0.9571** -0.9150**	-0.9586** -0.9108**	-0.9107** -0.8733**	-0.9574** -0.9243**	0.9914** 0.9266**
Kernel yield plant per plant(g)	G P	1.0000 1.0000	-0.275* 0.2417	-0.1938 -0.1186	0.5931** 0.5070**	-0.9982** -0.8040**	0.8685** 0.8400**	0.6636** 0.4652**	0.9359** 0.7849**	-0.9162** -0.7555**	0.9388** 0.7909**	0.4342** 0.2970*	-0.9494** -0.8574**	-0.9372** -0.8370**	-0.9795** -0.8617**	-0.9840** -0.8505**	-0.9679** -0.8515**	-0.9512** -0.8446**	0.9682** 0.9714**
Harvest index (%)	G P		1.0000 1.0000	0.6775** 0.3749**	-0.633** -0.2332	0.1273 0.0397	0.0203 0.0681	-0.5677** -0.3095*	0.2492 0.2012	-0.1980 -0.165	0.2663 0.2126	0.1112 0.0120	0.0099 -0.1587	0.0044 -0.1417	-0.0273 -0.1798	-0.1053 -0.1804	-0.1744 -0.2493	-0.3309* -0.3351*	0.4421** 0.3161*
Days to maturity	G P			1.0000 1.0000	-0.2872* -0.2156	0.2332 0.2173	-0.2248 -0.2041	-0.3857** -0.3248*	-0.0879 -0.0806	0.0752 0.0723	-0.0920 -0.0831	0.0310 0.0070	0.2384 0.2080	0.2530 0.2231	0.1939 0.1678	0.1478 0.1251	0.1007 0.0486	0.0299 0.0268	-0.1337 -0.0718
Shelling (%)	G P				1.0000 1.0000	-0.4481** -0.3897**	0.4133** 0.3646**	0.7761** 0.3501**	-0.8514** 0.1209	-0.1209 -0.1159	0.1317 0.1220	0.2996* 0.1847	-0.2795* -0.2618	-0.3024* -0.2699*	-0.3919** -0.3302*	-0.3926** -0.3536**	-0.4175** -0.3299*	-0.2352 -0.2235	0.3751** 0.2914*
LLS severity (%)	G P					1.0000 1.0000	-0.9482** -0.9463**	-0.7761** -0.7263**	-0.8514** -0.8492**	0.8333** 0.8321**	-0.8540** -0.8505**	-0.3600** -0.3121*	0.9523** 0.9256**	0.9498** 0.9295**	0.9305** 0.8942**	0.9045** 0.8928**	0.8345** 0.7922**	0.8338** 0.8133**	-0.9150** -0.7971**
Test weight (g)	G P						1.0000 1.0000	0.6937** 0.6505**	0.9059** 0.9051**	-0.8938** -0.8919**	0.9062** 0.9048**	0.3499** 0.3096*	-0.9809** -0.9571**	-0.9595** -0.9455**	-0.9725** -0.9388**	-0.9836** -0.9731**	-0.9589** -0.9181**	-0.9335** -0.9156**	0.9447** 0.8382**
SCMR	G P							1.0000 1.0000	0.5180** 0.4844**	-0.5520** -0.5113**	0.5036** 0.4722**	0.2539 0.2078	-0.6487** -0.5692**	-0.6370** -0.5717**	-0.5761** -0.5071**	-0.6161** -0.5618**	-0.5337** -0.4565**	-0.4378** -0.3900**	0.6401** 0.4412**
Non reducing sugar (mg/ g)	G P								1.0000 1.0000	-0.9909** -0.9883**	0.9989** 0.9985**	0.3319* 0.2962*	-0.9377** -0.9175**	-0.9116** -0.8979**	-0.9105** -0.8820**	-0.9043** -0.8955**	-0.8878** -0.8506**	-0.9508** -0.9340**	0.9520** 0.8404**
Reducing sugar (mg/ g)	G P									1.0000 1.0000	-0.9833** -0.9786**	-0.3020* -0.2651*	0.9237** 0.9030**	0.8927** 0.8757**	0.8902** 0.8607**	0.8884** 0.8790**	0.8729** 0.8284**	0.9322** 0.9113**	-0.8623** -0.8110**
Total sugar(mg /)	G P										1.0000 1.0000	0.3411* 0.3056*	-0.9385** -0.9175**	-0.9144** -0.9007**	-0.9137** -0.8845**	-0.9060** -0.8963**	-0.8892** -0.8537**	-0.9532** -0.9227**	0.9761** 0.8461**
Oil content (%)	G P											1.0000 1.0000	-0.2550 -0.2027	-0.2258 -0.2182	-0.3063* -0.2500	-0.3254* -0.2797*	-0.3527** -0.3023*	-0.3585** -0.3140*	0.4168** 0.2846*
Stomata frequency (Adaxial)	G P												1.0000 1.0000	0.9978** 0.9804**	0.9824** 0.9569**	0.9634** 0.9503**	0.9095** 0.8807**	0.9347** 0.9227**	-0.9301** -0.8844**
Stomata frequency (Abaxial)	G P													1.0000 1.0000	0.9786** 0.9552**	0.9498** 0.9385**	0.8840** 0.8632**	0.9137** 0.9075**	-0.9850** -0.8556**
Stomata length (µm) (Adaxial)	G P														1.0000 1.0000	0.9872** 0.9583**	0.9456** 0.9017**	0.9433** 0.9270**	-0.8760** -0.8675**
Stomata length (µm) (Abaxial)	G P															1.0000 1.0000	0.9918** 0.9480**	0.9550** 0.9445**	-0.9381** -0.8675**
Stomata breadth (µm) (Adaxial)	G P																1.0000 1.0000	0.9733** 0.9316**	-0.9753** -0.8531**
Stomata breadth (µm) (Abaxial)	G P																	1.0000 1.0000	-0.9434** -0.8720**

Table 3: Path coefficients for yield contributing and morpho-biochemical characters in Groundnut

Characters	No. of pod/ plant	Kernel yield (g)	Harvest index (%)	Days to maturity	Shelling %	LLS Severity (%)	Test weight (g)	SCMR	N.R. sugar (mg/g)	R. Sugar (mg/g)	Total Sugar (mg/g)	Oil content (%)	SF/mm² Ad (%)	SF/mm²Ab (%)	Stomata length (µm)		Stomata Breadth (µm)		Correlation with pod yield
															Ad	Ab	Ad	Ab	
No. of pod plant per plan (g)	G-**0.1602** P **0.0423**	0.0850 0.0379	0.0535 0.0107	0.1466 -0.0037	-0.3389 0.0113	0.0984 -0.0365	0.1305 0.0380	-0.7637 0.0228	-0.1394 0.0384	0.1392 -0.0380	-0.1345 0.0383	-0.4066 0.0117	0.1384 -0.0399	0.1181 -0.0393	0.1104 -0.0387	0.1122 -0.0385	0.0566 -0.0369	0.1108 -0.0391	0.9914** 0.9266**
Kernel yield plant per plant(g)	G0.5156 P 0.9786	**0.7207** **0.0912**	-0.4464 0.2637	-0.3141 -0.1294	0.9612 0.5533	-0.6177 -0.8774	0.6506 0.9166	0.0755 0.5076	0.5168 0.8565	-0.4849 -0.5076	0.5215 0.8630	0.7038 0.3241	-0.9487 -0.9357	-0.9190 -0.9133	-0.9874 -0.9403	-0.9948 -0.9281	-0.9686 -0.9292	-0.5416 -0.9216	0.9682** 0.9714**
Harvest index (%)	G0.0073 P -0.0005	0.0437 0.0004	**-0.1587** **-0.0018**	-0.1075 -0.0007	0.1005 0.0004	-0.0202 -0.0001	-0.0032 -0.0001	0.0901 0.0006	-0.0396 -0.0004	0.0314 0.0003	-0.0423 -0.0004	-0.0177 0.0000	-0.0016 0.0003	-0.0007 0.0003	0.0043 0.0003	0.0167 0.0003	0.0277 0.0005	0.0525 0.0006	0.4421** 0.3161*
Days to maturity	G-0.0481 P -0.0015	-0.0737 -0.0020	0.2576 0.0063	**0.3802** **0.0168**	-0.1092 -0.0036	0.0887 0.0036	-0.0855 -0.0034	-0.1467 -0.0054	-0.0334 -0.0014	0.0286 0.0012	-0.0350 -0.0014	0.0118 0.0001	0.0907 0.0035	0.0962 0.0037	0.0737 0.0028	0.0562 0.0021	0.0383 0.0008	0.0114 0.0004	-0.1337 -0.0718
Shelling (%)	G-0.0779 P -0.0728	-0.1581 -0.1382	0.1689 0.0636	0.0765 0.0588	**-0.2665** **-0.2726**	0.1194 0.1062	-0.1102 -0.0994	-0.1253 -0.0954	-0.0345 -0.0330	0.0322 0.0316	-0.0351 -0.0333	-0.0799 -0.0504	0.0745 0.0714	0.0806 0.0736	0.1045 0.0900	0.1046 0.0964	0.1113 0.0899	0.0627 0.0609	0.3751** 0.2914*
LLS severity (%)	G-0.4256 P -0.0068	-0.5030 -0.0063	0.1917 0.0003	0.3511 0.0017	-0.6747 -0.0031	**0.5057** **0.0078**	-0.4277 -0.0074	-0.1687 -0.0057	-0.2819 -0.0067	0.2547 0.0065	-0.2860 -0.0067	-0.5421 -0.0024	0.4339 0.0072	0.4302 0.0073	0.4011 0.0070	0.3620 0.0070	0.2565 0.0062	0.2555 0.0064	-0.9150** -0.7971**
Test weight (g)	G0.4810 P 0.0638	0.5027 0.0595	0.0100 0.0048	-0.1109 -0.0145	0.2040 0.0258	-0.4680 -0.0670	**0.4936** **0.0709**	0.3424 0.0461	0.4471 0.0641	-0.4412 -0.0632	0.4473 0.0641	0.1727 0.0219	-0.4842 -0.0678	-0.4736 -0.0670	-0.4800 -0.0665	-0.4855 -0.0689	-0.4733 -0.0651	-0.4608 -0.0649	0.9447** 0.8382**
SCMR	G0.2226 P 0.0025	0.2244 0.0021	-0.1919 -0.0014	-0.1304 -0.0015	0.1590 0.0016	-0.2624 -0.0033	0.2346 0.0030	**0.3381** **0.0046**	0.1751 0.0022	-0.1866 -0.0024	0.1703 0.0022	0.0858 0.0010	-0.2193 -0.0026	-0.2154 -0.0026	-0.1948 -0.0023	-0.2083 -0.0026	-0.1805 -0.0021	-0.1480 -0.0018	0.6401** 0.4412**
Non reducing sugar (mg/ g)	G-0.9169 P -0.8407	0.8737 0.7271	-0.2327 -0.1864	0.0820 0.0746	-0.1207 -0.1120	0.7948 0.7867	-0.8457 -0.8385	-0.4836 -0.4487	**-0.9336** **-0.9263**	0.9251 0.9155	-0.9325 -0.9250	-0.3099 -0.2744	0.8754 0.8499	0.8511 0.8317	0.8500 0.8170	0.8442 0.8295	0.8288 0.7879	0.8876 0.8652	0.9520** 0.8404**
Reducing sugar (mg/ g)	G0.1531 P 0.2245	-0.1428 -0.1886	0.0309 0.0414	-0.0117 -0.0180	0.0188 0.0289	-0.1299 -0.2077	0.1393 0.2226	0.0860 0.1276	0.1545 0.2467	**-0.1559** **-0.2496**	0.1533 0.2443	0.0471 0.0662	-0.1440 -0.2254	-0.1391 -0.2186	-0.1388 -0.2148	-0.1385 -0.2194	-0.1361 -0.2068	-0.1453 -0.2275	-0.8623** -0.8110**
Total sugar(mg /)	G 0.2433 P 0.6217	0.1936 0.5431	0.3386 0.1460	-0.1169 -0.0570	0.1675 0.0838	-0.6859 -0.5840	0.1522 0.6213	0.6403 0.3242	0.8700 0.6857	-0.2502 -0.6720	**0.9715** **0.6867**	0.4337 0.2099	-0.8933 -0.6300	-0.9626 -0.6185	-0.18617 -0.6074	-0.7519 -0.6154	-0.6306 -0.5862	-0.7120 -0.6433	0.9761** 0.8461**
Oil content (%)	G 0.0783 P 0.0025	0.0970 0.0027	0.0249 0.0001	0.0069 0.0001	0.0669 0.0017	-0.0804 -0.0029	0.0782 0.0028	0.0567 0.0019	0.0742 0.0027	-0.0675 -0.0024	0.0762 0.0028	**0.2234** **0.0091**	-0.0570 -0.0019	-0.0504 -0.0020	-0.0684 -0.0023	-0.0727 -0.0026	-0.0788 -0.0028	-0.0801 -0.0029	0.4168** 0.2846*
Stomata frequency (Adaxial)	G 0.4948 P 0.0411	-0.4787 -0.0373	-0.0050 0.0069	-0.1202 -0.0090	0.1409 0.0114	-0.4802 -0.0402	0.4946 0.0416	0.3271 0.0247	0.4728 0.0399	-0.4658 -0.0393	0.4732 0.0399	0.1286 0.0088	**-0.5042** **-0.0435**	-0.5031 -0.0426	-0.4954 -0.0416	-0.4858 -0.0413	-0.4586 -0.0383	-0.4713 -0.0401	-0.9301** -0.8844**
Stomata frequency (Abaxial)	G 0.6927 P -0.0250	-0.6462 -0.0225	-0.0077 -0.0038	-0.4444 0.0060	0.5312 -0.0073	-0.6682 0.0250	0.6853 -0.0254	0.1188 -0.0154	0.6012 -0.0241	-0.5679 0.0235	0.6060 -0.0242	0.3965 -0.0059	-0.7526 0.0264	**-0.7564** **0.0269**	-0.7189 0.0257	-0.6682 0.0252	-0.5526 0.0232	-0.6048 0.0244	-0.9850** -0.8586**
Stomata length (µm) (Adaxial)	G -0.3748 P 0.0174	-0.3836 -0.0164	-0.0107 0.0034	0.0759 -0.0032	-0.1534 0.0063	0.3644 -0.0170	-0.3808 0.0178	-0.2256 0.0096	-0.3565 0.0168	0.3486 -0.0164	-0.35780 0.0168	-0.1200 0.0048	0.3847 -0.0182	0.3832 -0.0182	**0.3916** **-0.0190**	0.3866 -0.0182	0.3703 -0.0171	0.3694 -0.0176	-0.8760** -0.8675**
Stomata length (µm) (Abaxial)	G -0.6620 P -0.0357	-0.6795 -0.0333	-0.0727 -0.0071	0.1020 0.0049	-0.2711 -0.0139	0.6246 0.0350	-0.6792 -0.0381	-0.4254 -0.0220	-0.6244 -0.0351	0.6135 0.0344	-0.6256 -0.0351	-0.2247 -0.0110	0.6653 0.0372	0.6558 0.0368	0.6817 0.0376	**0.6905** **0.0392**	0.6849 0.0372	0.6595 0.0370	-0.9381** -0.8486**
Stomata breadth (µm) (Adaxial)	G 0.0778 P -0.0014	-0.0827 -0.0013	0.0149 -0.0004	-0.0086 0.0001	0.0357 -0.0005	-0.0713 0.0012	0.0819 -0.0014	0.0456 -0.0007	0.0758 -0.0013	-0.0745 0.0013	0.0759 -0.00013	0.0301 -0.0005	-0.0777 0.0014	-0.0755 0.0014	-0.0808 0.0014	-0.0847 0.0015	**-0.0854** **0.0016**	-0.0831 0.0015	-0.9753** -0.8531**
Stomata breadth (µm) (Abaxial)	G -0.3098 P -0.8340	-0.3078 -0.0762	-0.1071 -0.0302	0.0097 0.0024	-0.0761 -0.0202	0.2698 0.0734	-0.3021 -0.0826	-0.1416 -0.0352	-0.3076 -0.0843	0.3016 0.0823	-0.3084 -0.0845	-0.1160 -0.0283	0.3024 0.0833	0.2956 0.0819	0.3052 0.0837	0.3090 0.0852	0.3149 0.0841	**0.3236** **0.0903**	-0.9434** -0.8720**

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