Research Article

Association of phytic acid towards the yield attributing traits in maize (*Zea Mays*. L)

J. Lydia Pramitha[1]* , G. Jeeva[2], A. John Joel[3], R. Ravikesavan[4] and Firoz Hossain[5]
[1,2]: Ph.D scholar, Center for Plant Breeding and Genetics, TNAU, Coimbatore
[3]: Professor, Tamil Nadu Rice Research Institute, Aduthurai
[4]: Professor and Head, Department of Millets, TNAU, Coimbatore
[5]: Senior Scientist, Indian council of Agricultural Research, New Delhi
E-Mail: lydiapramitha@gmail.com

Abstract
The current investigation was done to understand the role of phytic acid and its contribution to yield and yield attributing traits in maize. Phytic acid is an anti-nutritional factor involved in chelating phosphorus and other micronutrients in food. On contrary, it is a major regulator of the metabolic pathways in plants. This study involved the correlation and path analysis of nineteen morphological and two biochemical traits with phytic acid as the dependent factor. A significant positive correlation of seed girth, seed thickness, hundred seed weight, cob weight, starch content and single plant yield with phytic acid were observed. This elaborated the essentiality of phytic acid in seed set and pollination in maize. Consequently, this study also ensured the increase in free inorganic phosphorous content in reduced phytic acid lines through their negative association and revealed its chelating ability in foods. Further the path analysis established highest positive direct effect of single plant yield, seed girth, cob placement height, cob weight, days to 50 percent silking and cob girth towards the phytic acid content in maize. This reinforces the direct contribution of phytic acid in crop development. The correlation also encompasses the role of phytic acid in starch accumulation and seed thickness in maize by means of their positive association. Therefore, from this study it could be concluded that phytic acid has a functional relationship with the major yield contributing traits in maize. Hence proper selection criteria have to be followed for producing elite lines with low phytic acid in maize.

Keywords
Correlation and Path analysis, phytic acid, seed parameters, maize

Introduction

The availability and management of phosphorous in agriculture is a challenging global issue. The total phosphorous accumulated in seed crops portrays more than 50 per cent of the phosphorous fertilizers used in cultivation practices (Sparvoli and Eleonora, 2015). Phytic acid is the most abundant form of storage phosphorous in plants and it stores about 85 per cent of the phosphorous in cells. This phytic acid is degraded by phytase during germination and the required amount is released slowly for further development. Although, phytic acid is vital for plant's growth and metabolic pathways, its chelating ability leads to the deficiency of other micronutrients including phosphorous in food intake. The animals lacking phytase in their guts fail to process the phytate salts and the phytate-mineral complex in food. This salt complex is then excreted to the soil and water leading to eutrophication and mineral toxicity. Hence, humans and non-ruminants are in void of access to the actual nutrimental status of the maize seeds consumed (Zhou and Erdman,1995). This suggests that maize being a rich source of micronutrients fail to supplement them in diet due to the presence of phytic acid in their embryos.

Considering these issues, breeding for low phytic acid in maize has gained importance. On the other side, phytic acid is found to be a major regulator of auxin, cytokinin, chromatin modulation and also has key roles in pollination systems (Sparvoli and Eleonora,2015). Thus, breeding for low phytic acid in plants renders several pleiotropic issues such as stunted growth, poor yield and shriveled seeds. It was also reported that phytic acid was positively correlated to yield attributing traits. Therefore, with these views this study was conducted to understand the direct and indirect contributions of phytic acid to different morphological and biochemical parameters. This may further enhance the breeders with the traits to be concerned while going for combined approaches such as yield and low phytic acid in maize.

Materials and Methods
A set of 40 inbreds (Table 1) were raised in the Department of Millets, TNAU, Coimbatore in two replications. Nineteen morphological traits such as days to 50 per cent tasseling, days to 50 per cent silking, anthesis silking interval, cob placement height, plant height, tassel length, number of tassel

branches, cob length, cob girth, number of kernels per row, number of rows per cob, cob weight, shank weight, shelling percentage, seed length, seed girth, seed thickness, hundred seed weight and single plant yield and three biochemical traits namely, phytic acid, free inorganic phosphorous and starch were observed.

Phytic acid estimation: (Davies and Reid, 1979)
The finely grounded samples were weighed and 0.5 g of the grounded samples were taken in falcon tubes. Ten ml of 0.5M HNO3 was added to these falcon tubes and was kept in magnetic stirrer for three hours. After this extraction, 0.2 ml of the extract was taken and to this 0.2 ml of ferrous ammonium sulphate (2.16 mg/ml) was added. This was then kept in boiling water bath for 20 minutes. After cooling these tubes to room temperature, 0.02 ml of ammonium thiocyanate (5g/50 ml) and 1 ml of isoamyl alcohol were added. The tubes were shaken well and then centrifuged at 3000 rpm for ten minutes at 4^0C. The color developed was read at 460 nm.

Standard series for the estimation of phytic acid by Davies & Reid method

Concentration (mg/ml)	Working Standard (ml)	0.5 M HNO3 (ml)	Total volume (ml)
0.5	0.2	0	0.2
0.25	0.1	0.1	0.2
0.125	0.05	0.15	0.2
0.1	0.04	0.16	0.2
0.05	0.02	0.18	0.2
0.025	0.01	0.19	0.2
0	0	0.2	0.2

Free Inorganic Phosphorous Assay: (Chen et al., 1956)
Finely grounded maize samples of 0.1 g were taken in eppendorf tubes and 1 ml of 0.4 M HCl was added to it and kept in overnight for soaking at 0^0C. Next day the tubes were taken out. From these tubes,100 µl re of the extract were taken and added with 900 µl of freshly prepared Chen's reagent (6N H_2SO_4:2.5% ammonium molybdate: 10% ascorbic acid: H_2O [1:1:1:2, v/v/v/v]). The blue phosphomolybdate complex developed was read at 660 nm.

Standard series for the estimation of Free inorganic phosphorous assay

1mM KH2PO4 (µl)	0.5M HNO3 (µl)	Total volume (µl)
90	10	100
60	40	100
45	55	100
30	70	100
10	90	100
5	95	100
0	100	100

Estimation of Starch (Clegg, 1956):
Two gram grounded samples were homogenized with 80 per cent alcohol in a pestle and mortar. The homogenized samples were then taken in falcon tubes and centrifuged at 12000 rpm for 15 minutes. The ethanol washings were repeated and the samples were centrifuged with 80 per cent ethanol until the washings stopped giving color with anthrone. After that, the samples were dried in water bath and 5 ml of distilled water and 6.5 ml of 52 percent perchloric acid were kept for extraction at 20 0^0C for 20 minutes. The supernatant was collected in a volumetric flask. The extraction was repeated again with 52 per cent perchloric acid and the supernatant was pooled with the previously collected ones. The volume of the collected supernatants was made upto 100 ml with volumetric flask and 0.1 ml of the pooled extract were taken in test tubes and made upto 1 ml with distilled water. To this the freshly prepared 4 ml of anthrone reagent (200 mg/ 100 ml of 95% H_2SO_4) was added and heated in water bath for 8 minutes and the color was read at 630 nm.

Standard series: 100 mg/100 ml of standard glucose stock was prepared and from this stock 10 ml was taken and made upto 100 ml with distilled water. A series of 0.2,0.4,0.6 and 1 ml of the standard stock were taken and made upto 1 ml with water. To this, 4 ml of freshly prepared anthrone was added.

Statistical Analysis:
Correlation Coefficient
The genotypic correlation between phytic acid and yield component traits was worked out as per the method suggested by Johnson et al. (1955).

Genotypic correlation coefficient

$$r_{gxy} = (Cov.\,g(xy))/(\sigma 2gx . \sigma 2gy)^{1/2}$$

where,
rg (xy) =   genotypic correlation coefficients between x and y,
Covg (xy) =   genotypic covariance between the characters 'x' and 'y',
σ^2g.x   =   genotypic variance of the character 'x',
σ^2g.y   =   genotypic variance of the character 'y',
x   =   independent variable x, and
y   =   dependent variable y.
Testing the significance of $r_{g(xy)}$:

$$t = \frac{r_{xy}\sqrt{n-2}}{\sqrt{1-r_{xy}^2}}\ \text{ at t (n-2) df}$$

where,
    r = $r_{g(xy)}$ = genotypic correlation coefficients between the characters x and y,
    n = number of genotypes

Path coefficient analysis
The method of path coefficient analysis as suggested by Dewey and Lu (1959) was followed. The direct and indirect effects are classified based on the scale given below (Lenka and Mishra, 1973)

Path coefficients	Category
More than 1.00	Very high
0.30 to 0.99	High
0.20 to 0.29	Moderate
0.10 to 0.19	Low
0.00 to 0.09	Negligible

Results and Discussion
The morphological and biochemical traits observed in the 40 inbreds were subjected to statistical analysis for studying the correlation and association of various traits with phytic acid. The overall mean performance of the 40 inbreds are given in the table 2. Among the 40 inbreds raised, the lowest yield was observed in the genotype UMI 467 (31.37 g). This inbred was also found to have a lower phytic acid and starch content (2.86 mg/g & 57.32 %). The inbreds with a higher phytic acid content was found to perform better than the low phytate lines (Table 2). This illustrates us to understand the relationship of different traits with phytic acid in order to perform selection among the lines for potential donors.

The correlation of phytic acid to other morphological traits revealed, the highest positive significant correlation of seed girth (0.6213) and seed thickness (0.6213). This elaborates the role of phytic acid in seed health (Bregitzer et al.,2006 and Zhai et al.,2016). Also this shows that low phytic acid in maize would eventually result in shriveled seeds. Following them, hundred seed weight (0.5423) and cob weight (0.5033) were also found to be significantly correlated to phytic acid (Table 3). This states the concern of seed characters during introgression of low phytic acid in maize.

Starch is the major source of dry weight and energy in cereals. This association studies established a significant positive correlation of starch (0.4752) and single plant yield (0.4730) with phytic acid. This supports the previous investigations that myoinositiol in phytic acid pathway acts as a major transporter of starch from uridine di phosphate glucose (Lorenz et al.,2007). Thus perturbations in them results in poor accumulation of starch leading to poor yield levels in maize (Table 3). Hence, breeding for low phytic acid in maize ensures a careful selection of low phytic acid lines.

Although stringent reduction of phytic acid in maize results in adverse effects, the maize lines with moderate phytate and negative effects could be utilized in breeding programs to reduce the pleiotropic effects of low phytic acid (Raboy et al.,2000). Hence lines with moderate phytic acid content and yield levels like UMI 1099 (8.01 mg/g & 71.16 g) can be effectively used in low phytic acid breeding programs without compromising yield traits (Table 2).

The free inorganic phosphorous was observed to be negatively correlated (-0.9937) with phytic acid (Table 3). This suggests that the chelated phosphorous is released as the phytic acid content is reduced. Hence, this trait can be used as an indicator to screen the low phytic acid lines in maize (Suresh Kumar et al.,2015). The correlation in this study revealed a functional relationship among the variables with phytic acid. Further understanding their direction of association helps the breeders to determine appropriate selection indices in low phytate breeding programs. Keeping this in mind, path analysis was also studied to understand the role of phytic acid in yield attributing traits. The path analysis exhibited the highest positive direct contribution of single plant yield, seed girth, cob placement height, cob weight, days to 50 per cent silking and cob girth towards phytic acid (Table 4). This suggests the key role of phytic acid in yield parameters and silking (Latrasse et al.,2013).

The traits correlated to phytic acid also were observed to influence indirectly through several other parameters. The seed girth was found to moderately influence the phytic acid via seed yield per plant and high inorganic phosphorous. Seed thickness affects the phytic acid concentration by means of seed girth and high inorganic phosphorous (Lorenz et al.,2007). High indirect effect of hundred seed weight on phytic acid was observed through seed girth and single plant yield. The correlated starch moderately affects the phytic acid content through single plant yield and seed girth. Single plant yield was found to contribute indirectly through cob weight and high inorganic phosphorous. Cob weight affected phytic acid via single plant yield and moderately by seed girth. Cob girth influenced the accumulation of phytate via cob placement height and single plant yield (Table 4). Hence we can conclude that the phytic acid plays major role from silking to seed thickness in maize and alterations in their content would affect the seed yield parameters (Donahue et al.,2010). Therefore, stringent criteria have to adopted to overrule the linkages between seed yield attributing traits and phytic acid in near future.

This study also enlightens the breeders with the constraints that has to be surpassed in identifying potential donors for low phytic acid and presents the prerequisites in selection of parents for combined approaches involving yield and low phytic acid.

References

Bregitzer P, and Raboy V, 2006. Effects of four independent low-phytate mutations on barley agronomic performance. *Crop Science.* **46**(3):1318-1322.

Clegg K.M,1956. The application of the anthrone reagent to the estimation of starch in cereals. *Journal of the Science of Food and Agriculture.* **7**(1):40-44.

Davies, N.T, and Reid H,1979. An evaluation of the phytate, zinc, copper, iron and manganese contents of, and Zn availability from, soya-based textured-vegetable-protein meat-substitutes or meat-extenders. *British Journal of Nutrition*, **41**(3):579-589

Dewey, D.I. and Lu, K.H. 1959. A Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed Production. *Agronomy Journal*, **51,** 515-518

Donahue J.L, Alford S.R, Torabinejad J, Kerwin R.E, Nourbakhsh A, Ray W.K, Hernick M, Huang X, Lyons B.M, Hein P.P, and Gillaspy G.E,2010. The Arabidopsis thaliana myo-inositol 1-phosphate synthase1 gene is required for myo-inositol synthesis and suppression of cell death. *The Plant Cell***22**(3):888-903

Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimation of genetic and environmental variability in soybeans. *Agron. J.*, **47**: 314-318.

Latrasse D, Jegu T, Meng P.H, Mazubert C, Hudik E, Delarue M, Charon C, Crespi M,. Hirt H, Raynaud C, Bergounioux C.2013.Dual function of MIPS1 as a metabolic enzyme and transcriptional regulator. *Nucleic acids research* **41**(5) :2907-2917

Lorenz A.J, Scott M.P, and Lamkey K.R,2007. Quantitative determination of phytate and inorganic phosphorus for maize breeding. *Crop science* **47**(2):600-604.

Raboy V, Gerbasi P. F, Young K. A, S. Stoneberg D, Pickett S. G, Bauman A. T, Murthy P. P, Sheridan W. F, Ertl D.S.2000. Origin and seed phenotype of maize low phytic acid 1-1 and low phytic acid 2-1. *Plant physiology1* **24**(1):355-368

Sparvoli F, Cominelli E, (2015) Seed biofortification and Phytic acid reduction: a conflict of interest for the plant?.*Plants.* **4**(4):728-755

Sureshkumar. S, S.Narmatha, R.Mohana Priya, J.Ramalingam,M.Bharathi, N.Kumaravadivelu, P.Tamilkumar, S.Subhashini, M.Sivaji, N.Senthil, P.Nagarajan, S.Vellaikumar, K.N.Ganesan, R.Balagopal and M.Raveendran.2015. Simple protocol for maize single seed phytic acid estimation.*Annals of Plant science and soil research* 17(special issue) 391-395.

Zhou J.R, Erdman J.W.1995. Phytic acid in health and disease. *Critical Reviews in Food Science & Nutrition.* **35**(6):495-508.

Table 1. List of inbreds raised for the study

Code	Entries	Code	Entries
G1.	DMR-QPM-01-06-2	G21.	IMR-353
G2.	DMR-QPM-03-05-1	G22.	IMR-269
G3.	DMR-QPM-03-09-01	G23.	IMR-294
G4.	DMR-QPM-03-72	G24.	UMI-1099
G5.	DMR-QPM-04-05	G25.	UMI-467
G6.	DMR-QPM-06-12	G26.	UMI-447
G7.	DMR-QPM-06-20	G27.	UMI-300-1
G8.	DMR-QPM-06-20-1	G28.	UMI-158
G9.	DMR-QPM-08-04	G29.	UMI-113
G10.	DMR-QPM-08-07	G30.	IMR-326
G11.	DMR-QPM-09-07	G31.	IMR-314
G12.	DMR-QPM-09-13-1	G32.	IMR-271
G13.	DMR-QPM-09-15	G33.	IMR-19
G14.	DMR-QPM-10-04	G34.	IMR-225
G15.	DMR-QPM-10-06-2	G35.	IMR-255
G16.	DMR-QPM-10-11	G36.	IMR-118
G17.	DMR-QPM-11-04-2	G37.	IMR-29
G18.	DMR-QPM-11-17	G38.	IMR-20
G19.	DMR-QPM-215	G39.	LPA-2-285
G20.	IMR-335	G40.	LPA-2-395

Table 2. Mean performance of the 40 inbreds raised

	50 TE	50 SI	ASI	PL.HT	TL	TBR	CPH	CL	CG	R/CB	K/RW
G1	49.50	53.50	4.00	175.84	32.42	11.00	79.92	12.72	11.85	13.34	31.67
G2	52.50	56.50	4.00	144.34	34.17	12.17	76.34	19.00	12.83	14.34	24.13
G3	50.00	52.50	2.50	170.09	30.75	18.67	85.84	13.93	10.92	14.34	30.50
G4	49.50	52.50	3.00	185.17	36.25	19.50	89.67	16.50	13.50	14.34	25.24
G5	51.50	54.50	3.00	195.00	37.58	13.50	80.50	15.67	11.50	14.00	27.92
G6	54.50	57.50	3.00	152.67	37.17	17.34	73.92	14.40	9.64	12.67	28.34
G7	53.00	56.00	3.00	167.17	28.25	11.33	80.84	14.79	12.02	12.50	22.83
G8	51.50	54.00	2.50	179.59	34.34	18.83	64.92	15.50	9.67	11.33	25.83
G9	51.50	54.00	2.50	168.90	31.67	10.67	74.00	12.00	10.33	12.34	18.00
G10	50.50	53.50	3.00	175.02	34.08	13.34	87.67	15.00	10.40	12.00	29.84
G11	51.50	54.50	3.00	182.42	38.50	16.17	70.00	15.90	10.84	11.00	28.17
G12	51.00	56.00	5.00	155.92	30.83	18.34	77.75	14.25	10.92	11.67	28.33
G13	52.50	56.50	4.00	156.33	37.09	14.84	81.92	15.07	11.49	12.50	28.47
G14	50.50	53.50	3.00	156.42	37.00	12.00	59.09	13.35	8.42	13.34	25.17
G15	51.00	53.00	2.00	142.49	34.17	16.67	78.17	14.85	10.13	12.34	28.84
G16	51.50	54.50	3.00	189.25	37.08	15.17	71.08	12.85	10.95	10.00	26.97
G17	51.50	53.50	2.00	104.75	23.75	11.83	50.17	13.25	9.75	11.34	27.50
G18	51.50	53.50	2.00	130.32	24.68	15.34	73.92	11.77	10.85	12.34	29.84
G19	50.50	52.50	2.00	134.67	29.42	14.34	67.42	12.83	11.25	13.34	20.47
G20	56.50	58.50	2.00	193.92	30.84	11.33	92.67	15.00	11.25	11.83	15.00
G21	54.50	56.50	2.00	144.92	29.09	13.50	69.83	9.33	10.10	12.34	23.17
G22	54.50	57.50	3.00	155.75	27.84	16.00	79.50	13.25	12.08	12.50	19.50
G23	55.50	58.50	3.00	128.14	28.17	16.83	74.87	16.17	9.92	9.84	24.39
G24	54.50	57.50	3.00	132.50	26.97	10.34	71.92	10.94	10.00	12.34	28.17
G25	56.00	59.00	3.00	98.50	25.17	9.34	52.75	8.67	3.17	10.67	15.67
G26	50.50	52.50	2.00	128.00	37.17	16.84	52.50	12.17	8.84	11.84	25.50
G27	51.00	53.50	2.50	123.83	25.25	14.50	78.84	12.50	10.50	11.84	23.17
G28	49.50	52.50	3.00	107.67	21.17	15.00	48.67	12.40	10.03	14.30	20.35
G29	51.50	54.50	3.00	139.20	36.24	7.84	56.50	16.67	11.83	11.67	29.17
G30	53.00	57.00	4.00	128.69	18.92	16.50	78.75	13.37	10.87	14.00	26.00
G31	59.50	61.50	2.00	134.29	30.00	18.00	75.84	12.72	12.50	14.83	22.55
G32	56.50	58.50	2.00	132.59	22.42	9.50	68.84	11.84	9.84	12.50	20.98
G33	55.50	58.00	2.50	167.36	32.50	16.67	55.00	15.42	12.24	13.50	25.67
G34	55.50	58.50	3.00	119.50	29.59	9.67	69.58	11.67	7.75	12.50	21.17
G35	54.00	56.00	2.00	132.42	21.84	21.25	67.42	11.67	7.50	11.17	23.82
G36	57.00	59.00	2.00	156.42	26.00	9.34	68.59	11.75	9.34	11.67	16.84
G37	57.00	59.50	2.50	156.38	26.25	12.67	70.92	13.25	11.42	13.50	27.22
G38	56.50	59.50	3.00	150.58	30.75	13.17	75.25	14.84	10.12	12.33	26.06
G39	58.00	60.50	2.50	187.67	38.12	12.67	89.00	13.64	10.85	12.67	24.17
G40	56.50	59.50	3.00	190.11	36.07	18.00	79.40	15.71	12.38	13.29	29.34

Table 2. Cont,…

	CB Wt (g)	SH.Wt (g)	SH%	SL	SG	ST	HIP	STR	100 swt	SPY	PA
G1	89.62	19.17	82.31	0.74	0.52	0.33	0.28	59.04	21.34	70.45	13.89
G2	82.17	28.67	77.77	0.93	0.79	0.40	0.29	63.01	26.17	53.51	13.69
G3	89.05	14.00	84.75	0.77	0.67	0.37	0.30	65.49	20.41	75.05	13.25
G4	90.48	23.67	77.25	0.80	0.65	0.38	0.30	72.19	24.99	66.81	13.29
G5	89.58	18.17	79.50	0.87	0.59	0.35	0.34	56.44	22.92	71.41	12.22
G6	78.07	15.50	84.41	0.90	0.77	0.37	0.29	68.07	23.04	62.57	13.38
G7	69.87	23.50	79.85	0.85	0.69	0.35	0.37	56.25	24.41	46.37	12.18
G8	72.32	20.00	71.31	0.79	0.77	0.50	0.34	63.72	24.82	52.32	12.23
G9	59.10	17.90	67.35	0.85	0.72	0.45	0.32	63.49	25.28	41.20	12.95
G10	71.78	22.90	70.84	0.63	0.67	0.67	0.66	61.43	20.05	48.89	10.93
G11	86.67	24.67	68.89	0.85	0.83	0.45	0.30	56.20	28.12	62.00	13.57
G12	83.69	18.50	80.96	0.80	0.70	0.48	0.37	67.83	27.48	65.19	11.68
G13	89.91	17.50	83.94	0.90	0.70	0.32	0.62	62.13	25.25	72.41	12.09
G14	82.20	11.83	78.39	0.82	0.69	0.40	0.30	59.67	21.93	70.37	14.17
G15	72.38	20.17	73.12	0.82	0.62	0.35	0.61	60.77	20.43	52.21	10.75
G16	68.05	16.34	76.94	0.83	0.77	0.47	0.30	55.60	17.82	51.72	13.20
G17	70.68	18.83	70.54	0.87	0.57	0.39	0.27	56.44	19.82	51.85	11.81
G18	91.03	18.34	82.96	0.77	0.75	0.42	0.35	74.65	24.76	72.69	13.45
G19	63.82	18.00	72.27	0.79	0.70	0.37	0.33	63.80	22.04	45.82	13.45
G20	48.33	13.16	71.92	0.74	0.70	0.57	0.25	57.52	27.13	35.17	14.56
G21	56.75	17.67	67.82	0.70	0.57	0.35	0.35	58.09	19.42	39.09	12.79
G22	59.59	17.00	65.34	0.63	0.50	0.30	0.67	72.17	24.12	42.59	10.28
G23	64.38	14.50	70.80	0.79	0.64	0.49	0.35	59.05	24.70	49.88	12.99
G24	87.33	16.17	70.92	0.87	0.57	0.37	0.93	58.75	26.57	71.16	8.01
G25	40.04	8.67	87.06	0.68	0.67	0.39	1.98	57.32	17.90	31.37	2.86
G26	52.87	11.67	76.85	0.63	0.43	0.30	1.88	53.08	17.50	41.20	3.31
G27	58.54	16.67	74.70	0.87	0.47	0.40	0.95	51.17	22.84	41.88	7.83
G28	61.87	14.96	80.48	0.50	0.47	0.33	0.99	56.35	21.25	46.91	6.13
G29	70.14	12.00	85.40	0.63	0.47	0.33	0.87	64.98	20.62	58.14	8.13
G30	77.71	15.69	79.61	0.87	0.75	0.44	0.99	59.57	23.69	62.02	7.10
G31	80.55	12.00	79.96	0.80	0.65	0.45	0.35	60.24	26.44	68.55	12.77
G32	58.65	13.34	77.98	0.75	0.69	0.42	0.32	76.07	22.63	45.32	13.13
G33	91.05	24.31	81.09	0.87	0.73	0.40	0.30	69.32	29.13	66.74	13.78
G34	66.49	12.67	74.82	0.82	0.67	0.37	0.59	57.74	20.75	53.82	11.43
G35	61.45	12.23	73.09	0.79	0.66	0.38	0.38	76.17	23.19	49.22	12.55
G36	60.22	17.72	58.55	0.87	0.50	0.37	0.94	63.46	19.28	42.50	7.30
G37	77.85	15.17	73.53	0.78	0.68	0.62	0.27	67.35	21.22	62.68	13.80
G38	80.46	14.88	79.87	0.74	0.72	0.59	0.32	77.50	25.23	65.58	12.29
G39	56.20	16.67	83.23	0.89	0.64	0.35	1.87	53.29	21.68	39.53	2.74
G40	64.66	21.92	77.41	0.93	0.69	0.24	1.82	51.51	17.91	42.75	2.83

Table 3. Genotypic correlation of the Morphological traits to phytic acid

	50 TE	50 SI	ASI	PL.HT	TL	TBR	CPH	CL	CG	R/CB	K/RW	CB Wt (g)
50 TE	1											
50 SI	0.9673**	1										
ASI	-0.2490	0.0047	1									
PL.HT	-0.0457	-0.0094	0.1443	1								
TL	-0.3306*	-0.2688*	0.2769*	1.0248**	1							
TBR	-0.2859*	-0.2976*	-0.0092	0.1775	-0.2101	1						
CPH	0.1685	0.2464	0.2763*	0.7416**	0.6366**	0.3081*	1					
CL	-0.2732*	-0.1552	0.4847**	0.6503**	1.3791**	0.1457	0.6860**	1				
CG	-0.1627	-0.1039	0.245	0.6192**	0.4709**	-0.0691	0.8713**	0.5810**	1			
R/CB	-0.0425	-0.0097	0.1308	0.1371	0.0386	0.1235	0.2702*	0.2486	0.6740**	1		
K/RW	-0.4483**	-0.3670**	0.3657**	0.3093*	0.6677**	0.5145**	0.1966	0.5888**	0.4840**	0.179	1	
CB Wt (g)	-0.3328*	-0.229	0.4377**	0.3133*	0.5388**	0.3949**	0.3094*	0.5666**	0.6316**	0.4686**	0.7799**	1
SH.Wt	-0.3458*	-0.2788*	0.2989*	0.4813**	0.6593**	0.2369	0.3406*	0.6917**	0.7049**	0.2285	0.3706**	0.4642**
SH%	-0.3506*	-0.0877	1.0471**	-0.0072	0.4842**	-0.1304	0.1452	0.4198**	-0.0888	0.6154**	0.7088**	0.6717**
SL	0.2708	0.3410*	0.2341	0.4979**	0.6591**	0.2226	0.5895**	0.4090**	0.1679	0.1160	0.3294*	0.6194**
SG	0.1758	0.2496	0.2603*	0.4452**	0.4566**	0.3820**	0.3000*	0.4753**	-0.0998	-0.0781	0.1855	0.3811**
ST	0.2513	0.2401	-0.0741	0.2462	-0.2021	0.0153	0.2848*	0.2858*	0.0218	-0.3633**	0.0395	0.0158
HIP	0.2105	0.2172	-0.0007	-0.1923	0.0839	-0.1411	-0.1986	-0.3593**	-0.4563**	-0.1227	-0.1762	-0.5336**
STR	0.0905	0.0789	-0.0552	-0.0439	-0.3276*	0.2621	0.0653	0.0423	0.1021	0.109	0.0336	0.3020*
100 swt	0.1207	0.2000	0.2877*	0.1585	0.1271	0.3455**	0.3842**	0.4633**	0.4843**	0.2032	0.0903	0.5000**
SPY	-0.2582	-0.1647	0.3893**	0.1933	0.3863**	0.3617**	0.2339	0.4067**	0.4745**	0.4460**	0.7454**	0.9592**
PA	-0.1789	-0.1872	-0.0096	0.2564*	0.1157	0.1387	0.2809*	0.3613**	0.3951**	0.1102	0.1494	0.5033**

**significance at 1% level   * significance at 5% level

Table 3. Cont,..

	SH.Wt (g)	SH%	SL	SG	ST	HIP	STR	100 swt	SPY	PA
50 TE										
50 SI										
ASI										
PL.HT										
TL										
TBR										
CPH										
CL										
CG										
R/CB										
K/RW										
CB Wt (g)										
SH.Wt	1									
SH%	-0.3118*	1								
SL	0.6912**	-0.7049**	1							
SG	0.4908**	-0.1564	0.2828*	1						
ST	0.0747	-0.9260**	-0.3355**	0.4938**	1					
HIP	-0.2591	0.3789**	-0.2421	-0.5637**	-0.5233**	1				
STR	-0.0356	0.2069	-0.1594	0.3694**	0.3578*	-0.4904**	1			
100 swt	0.3699**	0.1210	0.5067**	0.5175**	0.3388*	-0.5554**	0.3974**	1		
SPY	0.195	0.8434**	0.4654**	0.2654*	-0.0064	-0.5082**	0.3458*	0.4357**	1	
PA	0.2641*	-0.2891*	0.2346	0.6213**	0.5571**	-0.9937**	0.4752**	0.5423**	0.4730**	1

**significance at 1% level   * significance at 5% level

Table 4. Path Analysis of the morphological traits to Phytic acid

	50 TE	50 SI	ASI	PL.HT	TL	TBR	CPH	CL	CG	R/CB	K/RW	CB Wt
50 TE	**-0.5204**	0.3132	0.1541	0.0248	-0.0216	0.0256	0.1086	0.0372	-0.0498	0.0216	0.3523	-0.1324
50 SI	-0.5034	**0.3238**	-0.0029	0.0051	-0.0176	0.0266	0.1588	0.0211	-0.0318	0.0049	0.2884	-0.0911
ASI	0.1296	0.0015	**-0.6187**	-0.0784	0.0181	0.0008	0.1781	-0.066	0.075	-0.0663	-0.2874	0.1741
PL.HT	0.0238	-0.003	-0.0893	**-0.5433**	0.0671	-0.0159	0.4779	-0.0885	0.1897	-0.0695	-0.2431	0.1246
TL	0.1721	-0.087	-0.1713	-0.5567	**0.0655**	0.0188	0.4103	-0.1877	0.1442	-0.0196	-0.5247	0.2143
TBR	0.1488	-0.0964	0.0057	-0.0964	-0.0138	**-0.0894**	0.1985	-0.0198	-0.0212	-0.0626	-0.4043	0.1571
CPH	-0.0877	0.0798	-0.1710	-0.4029	0.0417	-0.0276	**0.6445**	-0.0934	0.2669	-0.1371	-0.1545	0.1231
CL	0.1422	-0.0503	-0.2999	-0.3533	0.0903	-0.013	0.4421	**-0.1361**	0.178	-0.1261	-0.4627	0.2254
CG	0.0847	-0.0336	-0.1516	-0.3364	0.0308	0.0062	0.5615	-0.0791	**0.3063**	-0.3419	-0.3804	0.2512
R/CB	0.0221	-0.0032	-0.0809	-0.0745	0.0025	-0.011	0.1741	-0.0338	0.2065	**-0.5073**	-0.1406	0.1864
K/RW	0.2333	-0.1189	-0.2263	-0.1681	0.0437	-0.046	0.1267	-0.0802	0.1483	-0.0908	**-0.7858**	0.3102
CB Wt (g)	0.1732	-0.0741	-0.2708	-0.1702	0.0353	-0.0353	0.1994	-0.0771	0.1935	-0.2377	-0.6129	**0.3977**
SH.Wt	0.1799	-0.0903	-0.185	-0.2615	0.0432	-0.0212	0.2195	-0.0942	0.2159	-0.1159	-0.2912	0.1846
SH%	0.1824	-0.0284	-0.6479	0.0039	0.0317	0.0117	0.0936	-0.0571	-0.0272	-0.3122	-0.557	0.2672
SL	-0.1409	0.1104	-0.1448	-0.2705	0.0431	-0.0199	0.3799	-0.0557	0.0514	-0.0588	-0.2589	0.2464
SG	-0.0915	0.0808	-0.1611	-0.2419	0.0299	-0.0342	0.1933	-0.0647	-0.0306	0.0396	-0.1458	0.1516
ST	-0.1308	0.0777	0.0458	-0.1337	-0.0132	-0.0014	0.1835	-0.0389	0.0067	0.1843	-0.0311	0.0063
HIP	-0.1096	0.0703	0.0004	0.1045	0.0055	0.0126	-0.128	0.0489	-0.1398	0.0622	0.1385	-0.2122
STR	-0.0471	0.0256	0.0342	0.0238	-0.0214	-0.0234	0.0421	-0.0058	0.0313	-0.0553	-0.0264	0.1201
100 swt	-0.0628	0.0648	-0.178	-0.0861	0.0083	-0.0309	0.2476	-0.0631	0.1484	-0.1031	-0.0709	0.1989
SPY	0.1344	-0.0533	-0.2409	-0.105	0.0253	-0.0323	0.1508	-0.0554	0.1454	-0.2262	-0.5857	0.3815

Table 4. Cont..,

	SH.Wt (g)	SH%	SL	SG	ST	HIP	STR	100 swt	SPY	PA
50 TE	-0.0901	-0.0228	-0.1259	0.1293	-0.0206	-0.0833	-0.0319	-0.025	-0.2222	-0.1795
50 SI	-0.0727	-0.0057	-0.1585	0.1836	-0.0197	-0.0859	-0.0278	-0.0414	-0.1418	-0.1879
ASI	0.0779	0.068	-0.1088	0.1915	0.0061	0.0003	0.0194	-0.0596	0.3351	-0.0096
PL.HT	0.1255	-0.0005	-0.2314	0.3274	-0.0202	0.0761	0.0155	-0.0328	0.1664	0.2564*
TL	0.1719	0.0315	-0.3063	0.3359	0.0166	-0.0332	0.1154	-0.0263	0.3325	0.1159
TBR	0.0618	-0.0085	-0.1035	0.281	-0.0013	0.0558	-0.0923	-0.0716	0.3113	0.1389
CPH	0.0888	0.0094	-0.2739	0.2206	-0.0234	0.0786	-0.0230	-0.0796	0.2013	0.2808*
CL	0.1803	0.0273	-0.1901	0.3496	-0.0234	0.1421	-0.0149	-0.096	0.3500	0.3614**
CG	0.1838	-0.0058	-0.0780	-0.0734	-0.0018	0.1805	-0.0360	-0.1003	0.4084	0.3952**
R/CB	0.0596	0.040	-0.0539	-0.0575	0.0298	0.0485	-0.0384	-0.0421	0.3839	0.1102
K/RW	0.0966	0.0461	-0.1531	0.1364	-0.0032	0.0697	-0.0118	-0.0187	0.6415	0.1497
CB Wt (g)	0.1210	0.0436	-0.2879	0.2803	-0.0013	0.2111	-0.1064	-0.1036	0.8256	0.5035**
SH.Wt	**0.2607**	-0.0203	-0.3212	0.361	-0.0061	0.1025	0.0125	-0.0766	0.1678	0.2643*
SH%	-0.0813	**0.0650**	0.3276	-0.115	0.076	-0.1499	-0.0729	-0.0251	0.7259	-0.289
SL	0.1802	-0.0458	**-0.4647**	0.208	0.0275	0.0958	0.0561	-0.105	0.4005	0.2344
SG	0.1280	-0.0102	-0.1314	**0.7355**	-0.0405	0.2230	-0.1301	-0.1072	0.2285	0.6211**
ST	0.0195	-0.0602	0.1559	0.3632	**-0.082**	0.2070	-0.1260	-0.0702	-0.0055	0.5570**
HIP	-0.0675	0.0246	0.1125	-0.4146	0.0429	**-0.3956**	0.1727	0.1151	-0.4374	-0.9939**
STR	-0.0093	0.0134	0.0741	0.2717	-0.0294	0.1940	**-0.3522**	-0.0823	0.2976	0.4752**
100 swt	0.0964	0.0079	-0.2355	0.3806	-0.0278	0.2197	-0.1399	**-0.2072**	0.3750	0.5422**
SPY	0.0508	0.0548	-0.2163	0.1952	0.0005	0.2010	-0.1218	-0.0903	**0.8607**	0.4732**

**significance at 1% level   * significance

50 TE- Days to 50 % Tasselling, 50 SI: days to 50 percent silking, ASI: anthesis silking interval,PL.HT: Plant height, CPH:cob placement height, TBR: number of tassel branches, TL: tassel length, CL: cob length, CG: cob girth, R/CB: rows per cob, K/RW: number of kernels per row, CB Wt: cob weight, SH.Wt:shank weight, SH%: shelling percentage, SL: seed length, SG: seed girth, ST: seed thickness, HIP: High free inorganic phosphorous (mg/g), STR: Starch percentage, 100 swt: hundred seed weight, SPY: single plant yield, PA: phytic acid (mg/g)