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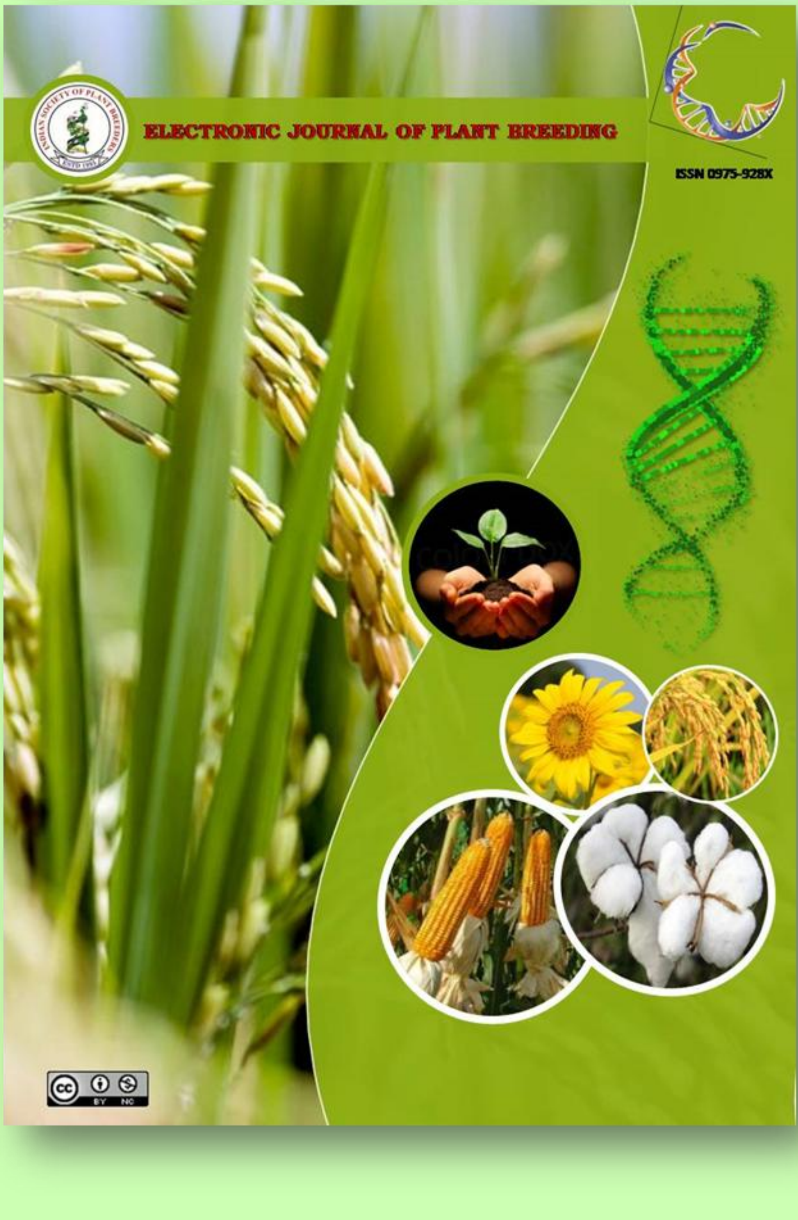


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**Research Article**

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

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**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

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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 at4$^{0}$C. 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$^{0}$C. 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$^{0}$C 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',

$\sigma^2$g.x = genotypic variance of the character 'x',

$\sigma^2$g.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

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**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.

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**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 |

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
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**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 |

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
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**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 |

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
ISSN 0975-928X

**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

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
ISSN 0975-928X

**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

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
ISSN 0975-928X

**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 |

Electronic Journal of Plant Breeding, 10 (3): 1019 - 1029 (Sep 2019) DOI: 10.5958/0975-928X.2019.00131.5
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**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)

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