**Character association and path coefficient analysis in spanish bunch groundnut (*Arachis hypogaea* L.)**

**ABSTRACT**

An experiment was conducted on 95 genotypes of spanish bunch groundnut in Randomized Block Design (RBD) design during 2022-23 in *Kharif* season, for studying the correlation between yield and its contributing traits. Correlation analysis identified traits such as number of primary branches per plant, number of mature pods, 100-pod weight, kernel yield per plant, 100-kernel weight, sound mature kernel, biological yield per plant, harvest index, oil content, and chlorophyll content at 30, 60, and 90 DAS as strong and consistent positive contributors to pod yield per plant, highlighted their importance in selection for yield improvement in Spanish bunch groundnut. Kernel yield per plant, biological yield per plant and harvest index had positive direct effects, along with significantly positive correlations in genotypic path; however, in phenotypic path, all the traits except days to 50% flowering, days to maturity, plant height and shelling percentage had positive direct effects with significantly positive correlations, indicating the importance of selecting these traits for improvement in pod yield per plant in Spanish bunch groundnut.

***Key Words:*** *Correlation analysis, Path analysis, Spanish bunch. groundnut, Chlorophyll, Oil content*

1. **INTRODUCTION**

Groundnut (*Arachis hypogaea* L.) is a major economic oilseed crop in the world, ranking as the 13th most significant food crop, the third most important vegetable protein source and the fourth-largest source of edible oil. It belongs to the *Leguminosae* (*Fabaceae*) family and is an annual herbaceous plant. In reference to the development of pods in the soil, the scientific name *Arachis hypogaea* L. is derived from two Greek words: *Arachis*, which means legume and *hypogaea*, which means below ground. Groundnuts have a basic chromosomal number of x = 10 and are an allotetraploid (2n = 4x = 40) (Stalker, 1991). It is primarily self-pollinating due to its cleistogamy (Knauft and Wynne, 1995). Groundnut is known worldwide by different colorful names, such as peanut in America and others like African nut, Earth chestnut, Chinese nut, Manila nut, Kipper nut, Monkey nut, Goober pea, Jar nut, Ground pea, Hawks nut and Ground bean (Johnson, 1964). It is generally known as Mungphali in India. Another well-known name for groundnuts is “The king of oilseeds”.

Groundnut is predominantly found in tropical, subtropical and warm temperate regions. Oilseed production holds significant importance in both developing and developed nations due to the wide gap between the demand and supply of edible oils. The majority of groundnut production is concentrated in Asian and African countries. Asia contributes approximately 50% of the global area and 60% of the world's groundnut production with India having the largest share of cultivated area (>20%), followed by China (>18%). However, China leads in total groundnut production accounting for 37% of the global output. The principal groundnut-producing countries include India, China, Nigeria, Senegal, Sudan and the United States of America. Groundnut is also a key oilseed and legume crop in India, fulfilling approximately 30% demand of the edible oil. In India, six states namely Gujarat, Maharashtra, Andhra Pradesh, Rajasthan, Karnataka and Tamil Nadu contribute about 90% groundnut cultivation area of the nation.

On average, groundnut seeds comprise 45% oil, 25% protein, 9% fibre, 6% sugar, 6% moisture and 2% minerals along with various vitamins and phytochemicals. Groundnut consumption is primarily determined by its oil, protein and sugar content and it is generally classified into oil types and confectionery types. The presence of vitamins and minerals further enhances its value as a medicinal and nutraceutical resource.

Groundnut is widely consumed as food or snacks and serves as a significant source of vegetable oil. Groundnut oil being edible, is extensively used as a cooking medium in the form of refined oil and vanaspati ghee. Groundnut is also rich in minerals like phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K), as well as vitamins from the B group and vitamin A. Its flexibility among oilseeds is notable, as it can be consumed and utilized in various forms. The chemical composition of groundnut such as protein and thiamine, is present in higher amounts than other dry fruits. Groundnut oil is considered stable and nutritious due to its optimal balance of oleic acid (40-50%) and linoleic acid (25-35%). With a high oil content (44-54%) and superior protein quality (24-30%), groundnut is valued for both edible oil production and confectionery applications. “Groundnut kernels are consumed in multiple forms; raw, roasted, boiled or fried are used in culinary products such as peanut milk, peanut butter, chocolates *etc*.” (Desai *et al.*, 1999).

Yield is complex character and it is composed of several components. Some of which affect the yield directly, while others affect indirectly. Hence, knowledge of association between yield and its components is necessary. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield. If the correlation is strong between a set of desirable traits, then we make selection for one character, the other character will automatically be taken care. If unfavorable association exists between desirable and undesirable traits, selection may result in genetic slippage and limit genetic advance. Direction and magnitude of correlation between yield and yield contributing characters must be considered for selection of superior genotypes from diverse genetic population but correlation does not provide information about direct and indirect effects of independent variable on dependent one. Thus, this path coefficient analysis is essential.

In a path coefficient analysis, which is given by Wright (1921) is standardized as partial regression coefficient, which helps in partitioning the correlation coefficient into direct and indirect effects of independent variables on dependent variable. One variable is measured by one's direct impact on another. Path coefficient analysis facilitates the selection process and enables breeders to select a genotype based on two or more traits simultaneously.

1. **MATERIALS AND METHODS**

The experimental material of the present investigation comprised of 95 genotypes of spanish bunch groundnut obtained from Main Oilseed Research Station, Junagadh Agricultural University, Junagadh during 2022-23 in *Kharif* seasons. The experiment was conducted in Randomized Block Design (RBD) with three replications. Each genotype was planted in a single row of 3.0 m length, 45 cm apart, with a 10 cm plant-to-plant spacing. To avoid damage and border effects, each experiment was surrounded by border rows. The recommended agronomical and plant protection practices were followed for successful raising of the crop.

The observations were recorded on pod yield per plant and other component traits like days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of mature pods per plant, 100-pod weight (g), kernel yield per plant (g), 100-kernel weight (g), shelling percentage (%), sound mature kernel (%), biological yield per plant (g), harvest index (%), oil content (%) and chlorophyll content at 30, 60 and 90 days after sowing (SPAD) to assess the correlations and path coefficients analysis in groundnut. Oil content was measured by Nuclear Magnetic Resonance (NMR) technique and chlorophyll content was measured by SPAD chlorophyll meter. The observations for all the characters were recorded on five randomly selected competitive plants for each genotype in each replication except for days to 50% flowering and days to maturity where observations were recorded on plot basis.

$$\begin{matrix}Shelling \left(\%\right) =&\frac{Weight of kernels (g)}{Weight of pod samples (g)}&×100\end{matrix}$$

$$\begin{matrix}Sound mature kernel (SMK \%) =&\frac{Number of well mature kernels }{Total number of kernels }&× 100\end{matrix}$$

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The analysis of variance for randomized block design (RBD) was done for each character with the method suggested by Panse and Sukhatme (1995). Genotypic (rg) and phenotypic (rp) correlation coefficients were calculated by adopting the method explained by Al-Jibouri *et al.* (1958). The genotypic and phenotypic path analysis was carried out as per the method suggested by Dewey and Lu (1959). Analysis was done in R-Studio software.

1. **RESULTS AND DISCUSSION**

In the present experiment genotypic (rg) and phenotypic (rp) correlation coefficients are computed and presented in Table 1. The results of the study are discussed below,

* 1. **Correlation coefficient analysis**

**3.1.1 Days to 50% flowering**

Days to 50% flowering had showed highly significant and positive correlation with days to maturity (rg= 0.353, rp= 0.230), number of primary branches per plant (rg= 0.692, rp= 0.525), biological yield per plant (rg= 0.510, rp= 0.329), oil content (rg= 0.358, rp= 0.308) at both genotypic and phenotypic levels. It showed highly significant positive correlation with chlorophyll content at 60 DAS (rg= 0.259, rp= 0.245) at phenotypic level and significant positive correlation at genotypic level. It showed significant and positive correlation with chlorophyll content at 90 DAS (rp= 0.121) at phenotypic level only. Days to 50% flowering had highly significant and negative correlation with sound mature kernel (rg= -0.471, rp= -0.267) and harvest index (rg= -0.466, rp= -0.336) at both genotypic and phenotypic levels.

**3.1.2 Days to maturity**

Days to maturityhad showed highly significant and positive correlation with number of primary branches per plant (rg= 0.303, rp= 0.232), biological yield per plant (rg= 0.308, rp= 0.224) and oil content (rg= 0.265, rp= 0.153) at both genotypic and phenotypic levels. It showed highly significant and positive correlation with plant height (rp= 0.153) at phenotypic level only. It also showed significant and positive correlation with chlorophyll content at 90 DAS (rg= 0.230, rp= 0.188) at genotypic level and highly significant and positive correlation at phenotypic level. While, days to maturityhad highly significant and negative correlation with sound mature kernel (rg= -0.307, rp= -0.163) and harvest index (rg= -0.435, rp= -0.278) at both genotypic and phenotypic levels.

**3.1.3 Plant height (cm)**

Plant height showed highly significant and positive correlation with biological yield per plant (rg= 0.284, rp= 0.241) at both genotypic and phenotypic levels. It showed significant and positive correlation with number of primary branches per plant (rp= 0.141) and number of mature pods per plant (rp= 0.140) at phenotypic level only. It also showed highly significant and positive correlation with chlorophyll content at 60 DAS (rg= 0.255, rp= 0.187) at phenotypic level and significant and positive correlation at genotypic level. Plant height showed highly significant and negative correlation with shelling percentage (rg= -0.305, rp= -0.180) and harvest index (rg= -0.295, rp= -0.191) at both genotypic and phenotypic levels. It also showed significant and negative correlation with 100-kernel weight (rg= -0.251, rp= -0.183) at genotypic level and highly significant and negative correlation at phenotypic level.

**3.1.4 Number of primary branches per plant**

Number of primary branches per plant showed highly significant and positive correlation with biological yield per plant (rg= 0.575, rp= 0.474), oil content (rg= 0.490, rp= 0.390), chlorophyll content at 60 DAS (rg= 0.484, rp= 0.366) and chlorophyll content at 90 DAS (rg= 0.406, rp= 0.294) at both genotypic and phenotypic levels. It also showed highly significant and positive correlation with number of mature pods per plant (rp= 0.162) and pod yield per plant (rg= 0.156) at phenotypic level only. On the other hand, the number of primary branches per plant exhibited highly significant and negative correlation with sound mature kernel (rg= -0.559, rp= -0.332) and harvest index (rg= -0.538, rp= -0.400) at both genotypic and phenotypic levels.

**3.1.5 Number of mature pods per plant**

Number of mature pods per plant demonstrated highly significant and positive correlation with kernel yield per plant (rg= 0.794, rp= 0.803), biological yield per plant (rg= 0.467, rp= 0.548), harvest index (rg= 0.311, rp= 0.240), oil content (rg= 0.299, rp= 0.249) and pod yield per plant (rg= 0.750, rp= 0.790) at both genotypic and phenotypic levels in E1. It showed highly significant and positive correlation with sound mature kernel (rp= 0.159) at phenotypic level. It also showed significant and positive correlation with chlorophyll content at 30 DAS (rp= 0.152) at phenotypic level only. On the other hand, number of mature pods per plant demonstrated highly significant and negative correlation with 100-kernel weight (rg= -0.327, rp= -0.309) at both genotypic and phenotypic levels. It also showed highly significant and negative correlation with 100-pod weight (rp= -0.189) at phenotypic level only.

**3.1.6 100-pod weight (g)**

Hundred pod weightshowed highly significant and positive correlation with kernel yield per plant (rg= 0.382, rp= 0.312), 100-kernel weight (rg= 0.910, rp= 0.823), harvest index (rg= 0.349, rp= 0.287), chlorophyll content at 90 DAS (rg= 0.264, rp= 0.239) and pod yield per plant (rg= 0.466, rp= 0.384) at both genotypic and phenotypic levels. It showed significant and positive correlation with sound mature kernel (rp= 0.135) at phenotypic level. It also showed significant and positive correlation with biological yield per plant (rg= 0.221, rp= 0.153) and chlorophyll content at 60 DAS (rg= 0.233, rp= 0.189) at genotypic level and highly significant and positive correlation at phenotypic level. In contrast, the 100-pod weightshowed highly significant and negative correlation with shelling percentage (rg= -0.354, rp= -0.234).

**3.1.7 Kernel yield per plant (g)**

Kernel yield per plant had highly significant and positive correlation with 100-kernel weight (rg =0.309, rp = 0.269), sound mature kernel (rg =0.265, rp = 0.197), biological yield per plant (rg =0.571, rp = 0.603), harvest index (rg =0.483, rp = 0.335) and pod yield per plant (rg =0.969, rp = 0.926) at both genotypic and phenotypic levels. It also showed significant and positive correlation with oil content (rg =0.262, rp = 0.228) at genotypic level and highly significant and positive correlation at phenotypic level.

**3.1.8 100-kernel weight (g)**

Hundred kernel weight had highly significant and positive correlation with harvest index (rg =0.328, rp = 0.201) and pod yield per plant (rg =0.316, rp = 0.203) at both genotypic and phenotypic levels. It also showed significant and positive correlation with sound mature kernel (rg =0.246, rp = 0.172) and chlorophyll content at 90 DAS (rg = 0.238, rp = 0.187) at genotypic level and highly significant and positive correlation at phenotypic level. It also showed significant and positive correlation with shelling percentage (rp = 0.142) at phenotypic level only.

**3.1.9 Shelling (%)**

Shelling percentage had highly significant and positive correlation with sound mature kernel (rg =0.293) at genotypic level only. However, shelling percentage expressed significant and negative correlation with biological yield per plant (rg= -0.250, rp= -0.207) at genotypic level and highly significant and negative correlation at phenotypic level. It showed highly significant and negative correlation with chlorophyll content at 60 DAS (rg= -0.354, rp= -0.148) at genotypic level and significant and negative correlation at phenotypic level. It also showed highly significant and negative correlation with pod yield per plant (rp = -0.269) at phenotypic level only.

**3.1.10 Sound mature kernel (%)**

During E1, sound mature kernel (%) had highly significant and positive correlation with harvest index (rg =0.296, rp = 0.249) at both genotypic and phenotypic levels. It also showed highly significant and positive correlation with pod yield per plant (rp = 0.188) at phenotypic level only. While, sound mature kernel showed highly significant and negative correlation with oil content (rg =-0.303, rp = -0.196) at both genotypic and phenotypic levels.

**3.1.11 Biological yield per plant (g)**

Biological yield per planthad highly significant and positive correlation with oil content (rg =0.331, rp = 0.248), chlorophyll content at 60 DAS (rg =0.449, rp = 0.296), chlorophyll content at 90 DAS (rg =0.358, rp = 0.225) and pod yield per plant (rg =0.617, rp = 0.651) at both genotypic and phenotypic levels. It also showed significant and positive correlation with chlorophyll content at 30 DAS (rp = 0.152) at phenotypic level only. However, biological yield per plant expressed highly significant and negative correlation with harvest index (rg= -0.402, rp= -0.436) at both genotypic and phenotypic levels.

**3.1.12 Harvest index (%)**

Harvest index had showed highly significant and positive correlation with pod yield per plant (rg =0.467, rp = 0.375) at both genotypic and phenotypic levels. However, harvest index expressed highly significant and negative correlation with chlorophyll content at 60 DAS (rg= -0.271, rp= -0.195) at both genotypic and phenotypic levels.

**3.1.13 Oil content (%)**

Oil content had showed highly significant and positive correlation with pod yield per plant (rg =0.307, rp = 0.249) at both genotypic and phenotypic levels. It showed significant and positive correlation with chlorophyll content at 90 DAS (rg =0.262, rp = 0.226) at genotypic level and highly significant and positive correlation at phenotypic level. It showed significant and positive correlation with chlorophyll content at 60 DAS (rp = 0.147) at phenotypic level only.

**3.1.14 Chlorophyll content at 30 DAS (SPAD)**

Chlorophyll content at 30 DAS had showed highly significant and positive correlation with chlorophyll content at 60 DAS (rg =0.303, rp = 0.281) and chlorophyll content at 90 DAS (rg =0.391, rp = 0.337) at both genotypic and phenotypic levels. It also showed significant and positive correlation with pod yield per plant (rp = 0.117) at phenotypic level only.

**3.1.15 Chlorophyll content at 60 DAS (SPAD)**

Chlorophyll content at 60 DAS had showed highly significant and positive correlation with chlorophyll content at 90 DAS (rg =0.570, rp = 0.497) at both genotypic and phenotypic levels. It also showed significant and positive correlation with pod yield per plant (rp = 0.125) at phenotypic level only.

**3.1.16 Chlorophyll content at 90 DAS (SPAD)**

Chlorophyll content at 90 DAS had showed significant and positive correlation with pod yield per plant (rg =0.210, rp = 0.135) at both genotypic and phenotypic levels. Chlorophyll content at 90 DAS showed significant and positive correlation with pod yield per plant (rg =0.212, rp = 0.138) at both genotypic and phenotypic levels in E2. In E3, chlorophyll content at 90 DAS showed highly significant and positive correlation with pod yield per plant (rg =0.303, rp = 0.220) at both genotypic and phenotypic levels.

**3.1.17 Pod yield per plant (g)**

Pod yield per plant showed highly significant and positive correlation with number of mature pods per plant (rg= 0.750, rp= 0.790), 100-pod weight (rg= 0.466, rp= 0.384), kernel yield per plant (rg= 0.969, rp= 0.926), 100-kernel weight (rg= 0.316, rp= 0.203), biological yield per plant (rg= 0.617, rp= 0.651), harvest index (rg= 0.467, rp= 0.375) and oil content (rg= 0.307, rp= 0.249) at both genotypic and phenotypic levels. It showed highly significant and positive correlation with number of primary branches per plant (rp= 0.156) and sound mature kernel (rp= 0.188) at phenotypic level only. It showed significant and positive correlation with chlorophyll content at 30 DAS (rp= 0.117) and chlorophyll content at 60 DAS (rp= 0.125) at phenotypic level only. It showed significant and positive correlation with chlorophyll content at 90 DAS (rg= 0.210, rp= 0.135) at both genotypic and phenotypic levels. However, pod yield per plant had highly significant and negative correlation with shelling percentage (rp= -0.269) at phenotypic level only.

Similar results were obtained for pod yield per plant by Vasanthi *et al*. (2015) with number of primary branches per plant, number of mature pods per plant and 100-kernel weight; Ashutosh *et al.* (2016) with 100-kernel weight, kernel yield per plant and harvest index; Mandal *et al*. (2017) with kernel yield per plant, sound mature kernel and harvest index; Hampannavar *et al*. (2018) and Kadam *et al*. (2018) with number of mature pods per plant; John and Reddy (2019) with sound mature kernel; Kumari and Sasidharan (2020) with number of mature pods per plant, 100-pod weight, kernel yield per plant, 100-kernel weight; Devarakonda *et al.* (2024) with harvest index and Sravanti *et al.* (2024) with 100-pod weight, 100-kernel weight, kernel yield per plant and sound mature kernel.

In conclusion, traits such as number of primary branches per plant, number of mature pods, 100-pod weight, kernel yield per plant, 100-kernel weight, sound mature kernel, biological yield per plant, harvest index, oil content and chlorophyll content at 30, 60 and 90 DAS emerged as strong and consistent positive contributors to pod yield per plant. These findings indicate that simultaneous improvement of these traits can be a strategic approach for enhancing pod yield in groundnut breeding programs, supported by their physiological basis and statistical significance.

**3.2 Path coefficient analysis**

Genotypic path analysis (Table 2) depicted that kernel yield per plant (0.9225) exhibited the highest positive direct effect on pod yield per plant, followed by harvest index (0.6677), biological yield per plant (0.5828), number of primary branches per plant (0.1314), sound mature kernel (0.0731), days to maturity (0.0446), chlorophyll content at 30 DAS (0.0418) and plant height (0.0320). While at phenotypic path (Table 3), highest positive direct effect was from kernel yield per plant (0.8020), followed by biological yield per plant (0.1173), harvest index (0.1102), number of mature pods per plant (0.0442), 100-pod weight (0.0197) and sound mature kernel (0.0102). For kernel yield per plant, biological yield per plant, harvest index, sound mature kernel, chlorophyll content at 30 DAS, number of primary branches per plant and plant height characters positive direct effects were found along with the positive genotypic correlations with the pod yield per plant; also, kernel yield per plant, biological yield per plant and harvest index had positive direct effects along with significantly positive correlations indicating the true relationship of these traits with the pod yield in groundnut.

Residual effects of genotypic and phenotypic path analysis 0.0020 and 0.0073, respectively. Low values of residual effects were found in all three environments indicating that the characters included in the study were enough to explain the variability in pod yield per plant in groundnut.

**Table 1. Genotypic and phenotypic correlation coefficients among different traits in groundnut**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   |   | **DM** | **PH** | **BPP** | **MPP** | **100PW** | **KYP** | **100KW** | **SP** | **SMK** | **BYP** | **HI** | **OC** | **CH 1** | **CH 2** | **CH 3** | **PY** |
| **DFF** | rg | 0.353\*\* | 0.148 | 0.692\*\* | 0.072 | -0.059 | 0.095 | -0.066 | -0.104 | -0.471\*\* | 0.510\*\* | -0.466\*\* | 0.358\*\* | 0.099 | 0.259\* | 0.136 | 0.118 |
| rp | 0.230\*\* | 0.077 | 0.525\*\* | 0.049 | -0.060 | 0.070 | -0.047 | -0.011 | -0.267\*\* | 0.329\*\* | -0.336\*\* | 0.308\*\* | 0.092 | 0.245\*\* | 0.121\* | 0.070 |
| **DM** | rg |  | 0.171 | 0.303\*\* | -0.022 | -0.115 | -0.064 | -0.116 | -0.050 | -0.307\*\* | 0.308\*\* | -0.435\*\* | 0.265\*\* | 0.125 | 0.068 | 0.230\* | -0.049 |
| rp |  | 0.153\*\* | 0.232\*\* | 0.014 | -0.071 | -0.007 | -0.107 | -0.050 | -0.163\*\* | 0.224\*\* | -0.278\*\* | 0.153\*\* | 0.084 | 0.024 | 0.188\*\* | 0.004 |
| **PH** | rg |  |  | 0.164 | 0.149 | -0.144 | -0.008 | -0.251\* | -0.305\*\* | 0.042 | 0.284\*\* | -0.295\*\* | 0.004 | -0.038 | 0.255\* | -0.148 | 0.067 |
| rp |  |  | 0.141\* | 0.140\* | -0.079 | 0.046 | -0.183\*\* | -0.180\*\* | 0.017 | 0.241\*\* | -0.191\*\* | 0.003 | -0.041 | 0.187\*\* | -0.108 | 0.108 |
| **BPP** | rg |  |  |  | 0.117 | -0.109 | 0.099 | -0.097 | -0.059 | -0.559\*\* | 0.575\*\* | -0.538\*\* | 0.490\*\* | 0.103 | 0.484\*\* | 0.406\*\* | 0.110 |
| rp |  |  |  | 0.162\*\* | -0.102 | 0.146\* | -0.082 | -0.046 | -0.332\*\* | 0.474\*\* | -0.400\*\* | 0.390\*\* | 0.100 | 0.366\*\* | 0.294\*\* | 0.156\*\* |
| **MPP** | rg |  |  |  |  | -0.199 | 0.794\*\* | -0.327\*\* | 0.156 | 0.163 | 0.467\*\* | 0.311\*\* | 0.299\*\* | 0.173 | -0.001 | 0.012 | 0.750\*\* |
| rp |  |  |  |  | -0.189\*\* | 0.803\*\* | -0.309\*\* | -0.031 | 0.159\*\* | 0.548\*\* | 0.240\*\* | 0.249\*\* | 0.152\* | -0.007 | -0.020 | 0.790\*\* |
| **100PW** | rg |  |  |  |  |  | 0.382\*\* | 0.910\*\* | -0.354\*\* | 0.182 | 0.221\* | 0.349\*\* | -0.048 | -0.045 | 0.233\* | 0.264\*\* | 0.466\*\* |
| rp |  |  |  |  |  | 0.312\*\* | 0.823\*\* | -0.234\*\* | 0.135\* | 0.153\*\* | 0.287\*\* | -0.043 | -0.050 | 0.189\*\* | 0.239\*\* | 0.384\*\* |
| **KYP** | rg |  |  |  |  |  |  | 0.309\*\* | 0.102 | 0.265\*\* | 0.571\*\* | 0.483\*\* | 0.262\* | 0.098 | 0.093 | 0.169 | 0.969\*\* |
| rp |  |  |  |  |  |  | 0.269\*\* | 0.102 | 0.197\*\* | 0.603\*\* | 0.335\*\* | 0.228\*\* | 0.102 | 0.071 | 0.100 | 0.926\*\* |
| **100KW** | rg |  |  |  |  |  |  |  | -0.038 | 0.246\* | 0.081 | 0.328\*\* | -0.082 | -0.105 | 0.117 | 0.238\* | 0.316\*\* |
| rp |  |  |  |  |  |  |  | 0.142\* | 0.172\*\* | 0.044 | 0.201\*\* | -0.053 | -0.080 | 0.103 | 0.187\*\* | 0.203\*\* |
| **SP** | rg |  |  |  |  |  |  |  |  | 0.293\*\* | -0.250\* | 0.117 | -0.160 | -0.154 | -0.354\*\* | -0.177 | -0.146 |
| rp |  |  |  |  |  |  |  |  | 0.036 | -0.207\*\* | -0.103 | -0.052 | -0.036 | -0.148\* | -0.096 | -0.269\*\* |
| **SMK** | rg |  |  |  |  |  |  |  |  |  | -0.058 | 0.296\*\* | -0.303\*\* | 0.107 | -0.185 | -0.154 | 0.190 |
| rp |  |  |  |  |  |  |  |  |  | -0.018 | 0.249\*\* | -0.196\*\* | 0.079 | -0.112 | -0.096 | 0.188\*\* |
| **BYP** | rg |  |  |  |  |  |  |  |  |  |  | -0.402\*\* | 0.331\*\* | 0.200 | 0.449\*\* | 0.358\*\* | 0.617\*\* |
| rp |  |  |  |  |  |  |  |  |  |  | -0.436\*\* | 0.248\*\* | 0.152\* | 0.296\*\* | 0.225\*\* | 0.651\*\* |
| **HI** | rg |  |  |  |  |  |  |  |  |  |  |  | 0.006 | -0.107 | -0.271\*\* | -0.135 | 0.467\*\* |
| rp |  |  |  |  |  |  |  |  |  |  |  | 0.004 | -0.081 | -0.195\*\* | -0.102 | 0.375\*\* |
| **OC** | rg |  |  |  |  |  |  |  |  |  |  |  |  | 0.109 | 0.191 | 0.262\* | 0.307\*\* |
| rp |  |  |  |  |  |  |  |  |  |  |  |  | 0.093 | 0.147\* | 0.226\*\* | 0.249\*\* |
| **CH 1** | rg |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.303\*\* | 0.391\*\* | 0.142 |
| rp |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.281\*\* | 0.337\*\* | 0.117\* |
| **CH 2** | rg |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.570\*\* | 0.183 |
| rp |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.497\*\* | 0.125\* |
| **CH 3** | rg |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.210\* |
| rp |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.135\* |

(rg = genotypic correlation coefficients; rp = phenotypic correlation coefficients; DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); BPP: Number of primary branches per plant; MPP: Number of mature pods per plant; PY: Pod yield per plant (g); 100PW: 100-pod weight (g); KYP: Kernel yield per plant (g); 100KW: 100-kernel weight (g); SP: Shelling percentage (%); SMK: Sound mature kernel (%); BYP: Biological yield per plant; HI: Harvest index (%); OC: Oil content (%); CH 1: Chlorophyll content at 30 DAS; CH 2: Chlorophyll content at 60 DAS; CH 3: Chlorophyll content at 90 DAS)

**Table 2. Genotypic path showing direct and indirect effects of various traits on pod yield in groundnut**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **DFF** | **DM** | **PH** | **BPP** | **MPP** | **100PW** | **KYP** | **100KW** | **SP** | **SMK** | **BYP** | **HI** | **OC** | **CH 1** | **CH 2** | **CH 3** | **Genotypic correlation with PY** |
| **DFF** | **-0.0059** | 0.0157 | 0.0047 | 0.0910 | -0.0431 | 0.0027 | 0.0874 | 0.0253 | 0.0132 | -0.0344 | 0.2970 | -0.3109 | -0.0196 | 0.0041 | -0.0081 | -0.0011 | 0.118 |
| **DM** | -0.0021 | **0.0446** | 0.0055 | 0.0398 | 0.0133 | 0.0052 | -0.0586 | 0.0443 | 0.0063 | -0.0224 | 0.1792 | -0.2904 | -0.0145 | 0.0052 | -0.0021 | -0.0018 | -0.049 |
| **PH** | -0.0009 | 0.0076 | **0.0320** | 0.0215 | -0.0893 | 0.0066 | -0.0074 | 0.0959 | 0.0385 | 0.0031 | 0.1653 | -0.1969 | -0.0002 | -0.0016 | -0.0080 | 0.0012 | 0.067 |
| **BPP** | -0.0041 | 0.0135 | 0.0052 | **0.1314** | -0.0702 | 0.0049 | 0.0909 | 0.0370 | 0.0075 | -0.0409 | 0.3350 | -0.3591 | -0.0269 | 0.0043 | -0.0152 | -0.0032 | 0.110 |
| **MPP** | -0.0004 | -0.0010 | 0.0048 | 0.0154 | **-0.5984** | 0.0091 | 0.7326 | 0.1249 | -0.0197 | 0.0119 | 0.2720 | 0.2079 | -0.0164 | 0.0072 | 0.0001 | -0.0001 | 0.750\*\* |
| **100PW** | 0.0004 | -0.0051 | -0.0046 | -0.0143 | 0.1191 | **-0.0455** | 0.3523 | -0.3473 | 0.0446 | 0.0133 | 0.1286 | 0.2329 | 0.0026 | -0.0019 | -0.0073 | -0.0021 | 0.466\*\* |
| **KYP** | -0.0006 | -0.0028 | -0.0003 | 0.0130 | -0.4753 | -0.0174 | **0.9225** | -0.1181 | -0.0129 | 0.0193 | 0.3329 | 0.3228 | -0.0144 | 0.0041 | -0.0029 | -0.0013 | 0.969\*\* |
| **100KW** | 0.0004 | -0.0052 | -0.0080 | -0.0127 | 0.1957 | -0.0414 | 0.2852 | **-0.3818** | 0.0048 | 0.0180 | 0.0474 | 0.2191 | 0.0045 | -0.0044 | -0.0037 | -0.0019 | 0.316\*\* |
| **SP** | 0.0006 | -0.0022 | -0.0098 | -0.0078 | -0.0936 | 0.0161 | 0.0943 | 0.0145 | **-0.1261** | 0.0214 | -0.1460 | 0.0781 | 0.0088 | -0.0064 | 0.0111 | 0.0014 | -0.146 |
| **SMK** | 0.0028 | -0.0137 | 0.0014 | -0.0735 | -0.0972 | -0.0083 | 0.2443 | -0.0939 | -0.0370 | **0.0731** | -0.0338 | 0.1975 | 0.0166 | 0.0045 | 0.0058 | 0.0012 | 0.190 |
| **BYP** | -0.0030 | 0.0137 | 0.0091 | 0.0756 | -0.2793 | -0.0100 | 0.5269 | -0.0310 | 0.0316 | -0.0042 | **0.5828** | -0.2685 | -0.0182 | 0.0083 | -0.0141 | -0.0028 | 0.617\*\* |
| **HI** | 0.0028 | -0.0194 | -0.0094 | -0.0707 | -0.1863 | -0.0159 | 0.4459 | -0.1253 | -0.0148 | 0.0216 | -0.2343 | **0.6677** | -0.0003 | -0.0045 | 0.0085 | 0.0011 | 0.467\*\* |
| **OC** | -0.0021 | 0.0118 | 0.0001 | 0.0644 | -0.1789 | 0.0022 | 0.2418 | 0.0314 | 0.0202 | -0.0222 | 0.1930 | 0.0039 | **-0.0548** | 0.0046 | -0.0060 | -0.0021 | 0.307\*\* |
| **CH 1** | -0.0006 | 0.0056 | -0.0012 | 0.0135 | -0.1037 | 0.0021 | 0.0906 | 0.0401 | 0.0195 | 0.0078 | 0.1163 | -0.0716 | -0.0060 | **0.0418** | -0.0095 | -0.0031 | 0.142 |
| **CH 2** | -0.0015 | 0.0030 | 0.0082 | 0.0636 | 0.0005 | -0.0106 | 0.0853 | -0.0447 | 0.0447 | -0.0135 | 0.2618 | -0.1808 | -0.0104 | 0.0127 | **-0.0313** | -0.0045 | 0.183 |
| **CH 3** | -0.0008 | 0.0102 | -0.0048 | 0.0533 | -0.0070 | -0.0120 | 0.1557 | -0.0907 | 0.0223 | -0.0112 | 0.2085 | -0.0898 | -0.0143 | 0.0163 | -0.0178 | **-0.0079** | 0.210\* |

**Residual=0.0020**; DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); BPP: Number of primary branches per plant; MPP: Number of mature pods per plant; 100PW: 100-pod weight (g); KYP: Kernel yield per plant (g); 100KW: 100-kernel weight (g); SP: Shelling percentage (%); SMK: Sound mature kernel (%); BYP: Biological yield per plant; HI: Harvest index (%); OC: Oil content (%); CH 1: Chlorophyll content at 30 DAS; CH 2: Chlorophyll content at 60 DAS; CH 3: Chlorophyll content at 90 DAS; PY: Pod yield per plant (g)

**Table 3. Phenotypic path showing direct and indirect effects of various traits on pod yield in groundnut**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **DFF** | **DM** | **PH** | **BPP** | **MPP** | **100PW** | **KYP** | **100KW** | **SP** | **SMK** | **BYP** | **HI** | **OC** | **CH 1** | **CH 2** | **CH 3** | **Phenotypic correlation with PY** |
| **DFF** | **0.0052** | -0.0007 | 0.0002 | 0.0027 | 0.0022 | -0.0012 | 0.0558 | -0.0001 | 0.0033 | -0.0027 | 0.0386 | -0.0370 | 0.0027 | 0.0007 | 0.0001 | 0.0001 | 0.070 |
| **DM** | 0.0012 | **-0.0032** | 0.0004 | 0.0012 | 0.0006 | -0.0014 | -0.0056 | -0.0001 | 0.0153 | -0.0017 | 0.0262 | -0.0307 | 0.0013 | 0.0006 | 0.0001 | 0.0002 | 0.004 |
| **PH** | 0.0004 | -0.0005 | **0.0028** | 0.0007 | 0.0062 | -0.0016 | 0.0371 | -0.0002 | 0.0554 | 0.0002 | 0.0282 | -0.0210 | 0.0001 | -0.0003 | 0.0001 | -0.0001 | 0.108 |
| **BPP** | 0.0028 | -0.0008 | 0.0004 | **0.0052** | 0.0071 | -0.0020 | 0.1168 | -0.0001 | 0.0140 | -0.0034 | 0.0556 | -0.0441 | 0.0034 | 0.0007 | 0.0001 | 0.0002 | 0.156\*\* |
| **MPP** | 0.0003 | -0.0001 | 0.0004 | 0.0008 | **0.0442** | -0.0037 | 0.6434 | -0.0004 | 0.0094 | 0.0016 | 0.0643 | 0.0264 | 0.0022 | 0.0011 | 0.0001 | -0.0001 | 0.790\*\* |
| **100PW** | -0.0003 | 0.0002 | -0.0002 | -0.0005 | -0.0083 | **0.0197** | 0.2503 | 0.0010 | 0.0722 | 0.0014 | 0.0179 | 0.0317 | -0.0004 | -0.0004 | 0.0001 | 0.0002 | 0.384\*\* |
| **KYP** | 0.0004 | 0.0001 | 0.0001 | 0.0008 | 0.0354 | 0.0061 | **0.8020** | 0.0003 | -0.0316 | 0.0020 | 0.0707 | 0.0370 | 0.0020 | 0.0007 | 0.0001 | 0.0001 | 0.926\*\* |
| **100KW** | -0.0003 | 0.0003 | -0.0005 | -0.0004 | -0.0137 | 0.0162 | 0.2158 | **0.0012** | -0.0438 | 0.0018 | 0.0051 | 0.0221 | -0.0005 | -0.0006 | 0.0001 | 0.0002 | 0.203\*\* |
| **SP** | -0.0001 | 0.0002 | -0.0005 | -0.0002 | -0.0014 | -0.0046 | 0.0820 | 0.0002 | **-0.3089** | 0.0004 | -0.0243 | -0.0114 | -0.0005 | -0.0003 | 0.0001 | -0.0001 | -0.269\*\* |
| **SMK** | -0.0014 | 0.0005 | 0.0001 | -0.0017 | 0.0070 | 0.0027 | 0.1576 | 0.0002 | -0.0110 | **0.0102** | -0.0021 | 0.0275 | -0.0017 | 0.0006 | 0.0001 | -0.0001 | 0.188\*\* |
| **BYP** | 0.0017 | -0.0007 | 0.0007 | 0.0025 | 0.0242 | 0.0030 | 0.4834 | 0.0001 | 0.0639 | -0.0002 | **0.1173** | -0.0480 | 0.0022 | 0.0011 | 0.0001 | 0.0002 | 0.651\*\* |
| **HI** | -0.0018 | 0.0009 | -0.0005 | -0.0021 | 0.0106 | 0.0057 | 0.2688 | 0.0002 | 0.0319 | 0.0026 | -0.0511 | **0.1102** | 0.0001 | -0.0006 | -0.0001 | -0.0001 | 0.375\*\* |
| **OC** | 0.0016 | -0.0005 | 0.0001 | 0.0020 | 0.0110 | -0.0009 | 0.1826 | -0.0001 | 0.0160 | -0.0020 | 0.0291 | 0.0004 | **0.0087** | 0.0007 | 0.0001 | 0.0002 | 0.249\*\* |
| **CH 1** | 0.0005 | -0.0003 | -0.0001 | 0.0005 | 0.0067 | -0.0010 | 0.0817 | -0.0001 | 0.0110 | 0.0008 | 0.0178 | -0.0089 | 0.0008 | **0.0072** | 0.0001 | 0.0003 | 0.117\* |
| **CH 2** | 0.0013 | -0.0001 | 0.0005 | 0.0019 | -0.0003 | 0.0037 | 0.0565 | 0.0001 | 0.0456 | -0.0012 | 0.0348 | -0.0215 | 0.0013 | 0.0020 | **0.0001** | 0.0004 | 0.125\* |
| **CH 3** | 0.0006 | -0.0006 | -0.0003 | 0.0015 | -0.0009 | 0.0047 | 0.0800 | 0.0002 | 0.0296 | -0.0010 | 0.0264 | -0.0112 | 0.0020 | 0.0024 | 0.0001 | **0.0008** | 0.135\* |

**Residual=0.0073**; DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); BPP: Number of primary branches per plant; MPP: Number of mature pods per plant; 100PW: 100-pod weight (g); KYP: Kernel yield per plant (g); 100KW: 100-kernel weight (g); SP: Shelling percentage (%); SMK: Sound mature kernel (%); BYP: Biological yield per plant; HI: Harvest index (%); OC: Oil content (%); CH 1: Chlorophyll content at 30 DAS; CH 2: Chlorophyll content at 60 DAS; CH 3: Chlorophyll content at 90 DAS; PY: Pod yield per plant (g)

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[DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); BPP: Number of primary branches per plant; MPP: Number of mature pods per plant; 100PW: 100-pod weight (g); KYP: Kernel yield per plant (g); 100KW: 100-kernel weight (g); SP: Shelling percentage (%); SMK: Sound mature kernel (%); BYP: Biological yield per plant; HI: Harvest index (%); OC: Oil content (%); CH 1: Chlorophyll content at 30 DAS; CH 2: Chlorophyll content at 60 DAS; CH 3: Chlorophyll content at 90 DAS; PY: Pod yield per plant (g)]

**Figure 1. Path diagram depicting genotypic correlation and direct effects of yield attributes on pod yield per plant**

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[DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); BPP: Number of primary branches per plant; MPP: Number of mature pods per plant; 100PW: 100-pod weight (g); KYP: Kernel yield per plant (g); 100KW: 100-kernel weight (g); SP: Shelling percentage (%); SMK: Sound mature kernel (%); BYP: Biological yield per plant; HI: Harvest index (%); OC: Oil content (%); CH 1: Chlorophyll content at 30 DAS; CH 2: Chlorophyll content at 60 DAS; CH 3: Chlorophyll content at 90 DAS; PY: Pod yield per plant (g)]

**Figure 2. Path diagram depicting phenotypic correlation and direct effects of yield attributes on pod yield per plant**

**CONCLUSION**

Pod yield is a polygenic and environmentally influenced trait; thus, correlation and path analysis are crucial for selecting high-yielding genotypes with desirable characteristics. Pod yield per plant showed a highly significant and positive correlation with number of mature pods per plant, 100-pod weight, kernel yield per plant, 100-kernel weight, biological yield per plant, harvest index, oil content and chlorophyll content at 90 DAS at both genotypic and phenotypic levels. While it showed highly significant and positive correlation with number of primary branches per plant, sound mature kernel at chlorophyll content at 30 DAS and 60 DAS at phenotypic level only. Genotypic path analysis indicated that kernel yield per plant, biological yield per plant and harvest index had positive direct effects, along with significantly positive correlations, while in phenotypic path, all the traits except days to 50% flowering, days to maturity, plant height and shelling percentage had positive direct effects with significantly positive correlations, indicating the true relationship of these traits with the pod yield in groundnut. Therefore, pay attention to the above-mentioned characteristics in addition to yield alone for increasing pod yield.

Disclaimer

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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