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# Studies on Selection Indices in Guar (*Cyamopsis tetragonaloba* (L.) Taub.)

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## ABSTRACT

The efficacy of the selection process is greatly enhanced by using appropriate selection indices. The knowledge of the relationship among various traits affecting grain yield is crucial to arrive at a potentially effective selection index. The present study was carried out to illuminate the nature and extent of interrelationships among various traits (including quality, physiological and yield related) affecting seed yield in guar (*Cyamopsis tetragonaloba* (L.) Taub.). Fifty guar accessions from different states Rajasthan, Gujarath, Haryana and Karnataka were evaluated in a randomized block design with three replications, during Kharif, 2005 at the Dryland Farm, RARS, Tirupati, India. Data was recorded on 21 quantitative traits and subjected to statistical analysis. The correlation studies revealed the positive and significant association of number of pods per plant, number of branches per plant, number of clusters per plant, number of seeds per pod, number of pods per cluster, harvest index, SCMR at 40 and 60 days after sowing with seed yield. Path analysis revealed that the number of pods per plant, SCMR at 40 DAS, number of seeds per pod and number of pods per cluster were important in formulating selection criteria for improvement of seed yield in guar.

**Keywords:** character association, direct and indirect effects, quality, SCMR

## INTRODUCTION

Guar or clusterbean (*Cyamopsis tetragonaloba* (L.) Taub.) is a drought-tolerant annual legume crop grown in many arid regions of the world. Tender green guar is an important source of nutrition to animals and humans and is consumed as a vegetable and cattle feed (Kumar 2002). Guar meal is also used as cattle feed owing to the presence of high protein content (40-42% on dry weight basis). Guar in recent years has achieved the status of an industrial crop, due to water soluble natural polymer galactomannon gum. This polysaccharide possesses remarkable rheological properties and consequently it is adopted as a thickener to control viscoelasticity in food, personal care, and oil recovery industries.

India accounts for 80% of the total guar produced in the world and 70 to 80% is cultivated in Rajasthan. It is grown in an area of 2.955 million ha with a production of 1.05 million tones and productivity of 350 kg ha-1 in India (Indiastat 2005-2006).

Guar has become an alternative remunerative crop with high adaptability suited for growing in arid regions of the World. It is a warm-weather loving, deep-rooted, summer-growing annual legume (www.rirdc.gov.au/pub/handbook/guar.pdf.).

Refined guar gum has a plethora of uses in various industries like textiles, confectionaries, cosmetics, explosives and oil industries owing to its unique characters like grease resistance, stability at low temperature, capacity to bind with water and its wide viscosity ranges (Kumar 2002).Guar gum acts as a binder, stabilizer or thickener in many products. The food industry shares 30-40%, petroleum and mining industries share around 20-25% and the textile industry shares almost 18-20% of total consumption of guar gums (Kumar 2005).

At the peak of its commercial importance, the price per quintal of guar seeds were around Rs. 1700-1800 (approximately $35) and the prices are expected to increase to about Rs.3000 (approximately $61) with the demand as the supply of this crop is limited due to the limited area of cultivation and erratic climatic factors (Karvy Comtrade Ltd. 2008). Its total output was valued at 10020.83 million Rs (approximately 202.44 million USD) by 2003-2004 including churi, korma and splits; Indiastat, 2005-2006). Splits are the galactomannon portion of the guar seeds (endosperm) from which the gum is extracted. Churi and korma are the by-products of guar which account for 29 and 31% of the total seed, respectively and are used as cattle feed (Karvy Comtrade Ltd. 2008, www.reliancemoney.co.in/cmt/upload/research/PN_guar.pdf).

Guar has assumed a great industrial importance in recent years in arid zones of the world mainly due to the presence of gum (galactomannan) in its endosperm, which constitutes about 30-32% of the whole seed (Kumar 2002). The specific colloidal nature of guar gum solution gives the solution an excellent thickening powder which is 6-10 times higher than that obtained from starch (Kumar 2005).

Apart from this, guar leaves have medicinal values to cure night blindness. Seeds are used as a chemotherapeutic agent against small pox and also as a laxative. Boiled guar seeds are used as poultices for the plague, enlarged livers, head swellings and on swellings due to broken bones. Guar also plays an important role in maintaining soil health and sustainability of production of other important non-leguminous crops/cropping systems (Kumar 2005).

The phenotype of a plant is the result of a large number of factors. Therefore the final yield is the sum total of all the effects of several component traits since it is a polygenically inherited character. Correlation analysis provides information on the nature and extent of relationship of different component traits with seed yield.

In the last few years several researchers have begun to undertake research work on guar focusing on its seed yield as well as its rheological properties.

Biological yield per plot, clusters per plant, days to flowering, days to maturity, pods per plant, plant height,

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branches per plant, 100-seed weight and harvest index traits were found to be the desirable characters associated with seed yield in cluster bean (Singh *et al.* 2005; Buttar *et al.* 2008).

Significant relationship of specific leaf area with both seed yield and relative water content suggested that low specific leaf area is a cost effective and easily measurable leaf trait and is a potential selection criterion for improving yield of cluster bean under rain-fed conditions of arid zone (Talwar *et al.* 2008).

When many characters are affecting a given trait, splitting the correlation into direct and indirect effects of cause devised by Wright (1921) would give more meaningful interpretation to the causes of association between the dependent variable like seed yield and independent variables like yield components.

Investigations on guar revealed highest positive direct effects of the characters like pods per plant, biological yield, branches per plant, plant height, seeds per pod and harvest index on seed yield. (Choudhary *et al.* 2004; Singh *et al.* 2005; Singh *et al.* 2005; Mahla *et al.* 2006; Buttar *et al.* 2008).

Keeping this in view, the present study was carried out to formulate selection strategies for improvement of seed yield in guar besides focusing on its quality aspects.

## MATERIALS AND METHODS

### Source of germplasm

Fifty genotypes of guar collected from Rajasthan, Gujarat, Haryana and Karnataka were evaluated in a randomized block design with three replications, during Kharif, 2005 at Dryland Farm, RARS, Tirupati. Each genotype was sown in three rows of 4 m length with a spacing of 30 cm between rows and 10 cm between plants.

Ten competitive plants were tagged in each genotype in each replication and observations were recorded for 21 characters viz., days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, number of seeds per pod, 100 seed weight (g), harvest index, SPAD (soil plant analytical development) chlorophyll meter reading at 40 days after sowing (using Minolta chlorophyll meter SPAD-502), SPAD chlorophyll meter reading at 60 days after sowing, leaf area index at 50 days after sowing, specific leaf area at 40 days after sowing ($cm^2/g$)(using LI-COR model-3000), specific leaf area at 60 days after sowing ($cm^2/g$), protein content (%) (Lowry *et al.* 1951), carbohydrate content (%) (Dubois *et al.* 1956) endosperm percentage (%), gum content (%), viscosity (cPa/s) (using Haake Rotoviscometer RV-20 model, Germany) and seed yield per plant (g) were used for statistical analysis. Procedures for extraction of gum (including endosperm percentage) were developed by Das *et al.*

**Table 1** Phenotypic ($r_p$) and Genotypic ($r_g$) correlation coefficients among seed yield and its components in guar.

| **Character** | | **Days to 50% flowering** | **Days to maturity** | **Plant height (cm)** | **№ of branches / plant** | **№ of clusters / plant** | **№ of pods / cluster** | **№ of pods / plant** | **№ of seeds per pod** | **100-seed weight (g)** | **Harvest index** | **SCMR at 40 DAS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50 % | $r_p$ | 1.000 | 0.4773** | 0.2712 | -0.3125 | -0.1985 | 0.2091 | -0.1491 | 0.0528 | -0.1984 | -0.1221 | -0.4042* |
| flowering | $r_g$ | 1.000 | 0.5380** | 0.3406* | -0.3901* | -0.2579 | 0.2091 | -0.1555 | 0.0725 | -0.2270 | -0.1395 | -0.5507** |
| Days to maturity | $r_p$ | | 1.000 | 0.6145** | -0.4306* | -0.3387 | -0.1206 | -0.3401* | 0.1021 | -0.0480 | -0.2628 | -0.4328* |
| | $r_g$ | | 1.000 | 0.6640** | -0.4787** | -0.3925* | -0.1405 | -0.3532* | 0.1518 | -0.0580 | -0.2775 | -0.4993** |
| Plant height (cm) | $r_p$ | | | 1.000 | -0.1128 | 0.0201 | -0.0613 | -0.0240 | 0.2080 | 0.2201 | -0.1090 | -0.2980 |
| | $r_g$ | | | 1.000 | -0.1497 | 0.0148 | -0.1132 | -0.0342 | 0.3931* | 0.2400 | -0.1285 | -0.3233 |
| № of branches / | $r_p$ | | | | 1.0000 | 0.7461** | 0.1035 | 0.6301** | -0.1008 | 0.0439 | 0.2515 | 0.4032* |
| plant | $r_g$ | | | | 1.0000 | 0.8618** | 0.1457 | 0.7140** | -0.1160 | 0.0416 | 0.2618 | 0.5752** |
| № of clusters / | $r_p$ | | | | | 1.0000 | 0.1343 | 0.6877** | 0.0883 | 0.1528 | 0.1631 | 0.4070* |
| plant | $r_g$ | | | | | 1.0000 | 0.1946 | 0.7713** | 0.1249 | 0.1687 | 0.1787 | 0.5067** |
| № of pods / cluster | $r_p$ | | | | | | 1.0000 | 0.5157** | 0.0915 | 0.1195 | 0.0656 | 0.0922 |
| | $r_g$ | | | | | | 1.0000 | 0.6042** | 0.2210 | 0.1460 | 0.0583 | 0.1442 |
| № of pods / plant | $r_p$ | | | | | | | 1.0000 | 0.1425 | 0.2284 | 0.4104* | 0.3549* |
| | $r_g$ | | | | | | | 1.0000 | 0.1529 | 0.2434 | 0.3979* | 0.4160* |
| № of seeds per pod | $r_p$ | | | | | | | | 1.0000 | 0.2688 | 0.0751 | -0.0524 |
| | $r_g$ | | | | | | | | 1.0000 | 0.4969** | 0.0836 | -0.1069 |
| 100-seed weight | $r_p$ | | | | | | | | | 1.0000 | 0.1062 | 0.2385 |
| (g) | $r_g$ | | | | | | | | | 1.0000 | 0.1139 | 0.2821 |
| Harvest index | $r_p$ | | | | | | | | | | 1.0000 | 0.0426 |
| | $r_g$ | | | | | | | | | | 1.0000 | 0.0693 |
| SCMR at 40 DAS | $r_p$ | | | | | | | | | | | 1.0000 |
| | $r_g$ | | | | | | | | | | | 1.0000 |
| SCMR at 60 DAS | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| LAI at 50 DAS | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| SLA at 40 DAS | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| SLA at 60 DAS | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| Protein content | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| Carbohydrate | $r_p$ | | | | | | | | | | | |
| content | $r_g$ | | | | | | | | | | | |
| Endosperm (%) | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| Gum content (%) | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| Viscosity | $r_p$ | | | | | | | | | | | |
| | $r_g$ | | | | | | | | | | | |
| Seed yield | $r_p$ | | | | | | | | | | | |

**Table 1** (Cont.)

| Character | | SCMR at 60 DAS | LAI at 50 DAS | SLA at 40 DAS | SLA at 60 DAS | Protein Content | Carbohydrate content | Endosperm (%) | Gum content (%) | Viscosity | Seed yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50 % | $r_p$ | -0.5235** | 0.2060 | 0.3373 | 0.2705 | 0.1134 | -0.2269 | -0.1350 | -0.1441 | 0.0511 | -0.2196 |
| flowering | $r_g$ | -0.6574** | 0.2626 | 0.3930* | 0.3615* | 0.1531 | -0.2749 | -0.1431 | -0.1552 | 0.0536 | -0.2567 |
| Days to | $r_p$ | -0.5938** | 0.4097* | 0.3299 | 0.2579 | 0.0587 | -0.1281 | 0.0259 | 0.0201 | -0.0145 | -0.4046* |
| maturity | $r_g$ | -0.6627** | 0.4323* | 0.3795* | 0.3404* | 0.0539 | -0.1441 | 0.0299 | 0.0251 | -0.0205 | -0.4349* |
| Plant height | $r_p$ | -0.4790** | 0.5071** | 0.0352 | 0.3211 | 0.0964 | 0.0535 | 0.0303 | 0.0724 | -0.1619 | -0.0021 |
| (cm) | $r_g$ | -0.5342** | 0.5389** | 0.0282 | 0.3916* | 0.0823 | 0.0397 | 0.0392 | 0.0773 | -0.1732 | -0.0140 |
| № of branches / | $r_p$ | 0.3568* | -0.1676 | -0.3030 | 0.0187 | -0.0506 | 0.1941 | 0.1029 | 0.1351 | -0.2925 | 0.6797** |
| plant | $r_g$ | 0.4304 | -0.1927 | -0.3390* | 0.0055 | -0.1052 | 0.2291 | 0.1177 | 0.1602 | -0.3246 | 0.7590** |
| № of clusters / | $r_p$ | 0.2448 | -0.0691 | -0.2564 | 0.0477 | -0.0799 | 0.2528 | 0.0819 | 0.1083 | -0.2985 | 0.6919** |
| plant | $r_g$ | 0.3189 | -0.0961 | -0.3070 | 0.1091 | -0.0957 | 0.3178 | 0.0892 | 0.1336 | -0.3284 | 0.7567** |
| № of pods / | $r_p$ | 0.2003 | -0.3256 | 0.1201 | -0.0124 | -0.0586 | 0.0669 | -0.1017 | -0.0762 | -0.1453 | 0.4090* |
| cluster | $r_g$ | 0.2458 | -0.4137* | 0.1856 | -0.0098 | -0.1040 | 0.0638 | -0.1164 | -0.0910 | -0.1716 | 0.4753** |
| № of pods / | $r_p$ | 0.3733* | -0.2429 | -0.0890 | -0.0011 | -0.0926 | 0.2556 | 0.1268 | 0.1596 | -0.2950 | 0.8593** |
| plant | $r_g$ | 0.4257* | -0.2630 | -0.0962 | -0.0055 | -0.1007 | 0.2687 | 0.1278 | 0.1544 | -0.3029 | 0.8816** |
| № of seeds per | $r_p$ | -0.0744 | -0.0539 | 0.0373 | 0.0231 | -0.0571 | 0.0616 | 0.0785 | 0.1004 | 0.0529 | 0.4394** |
| pod | $r_g$ | -0.0514 | -0.0683 | 0.0451 | 0.0111 | 0.0742 | 0.0535 | 0.1503 | 0.1571 | 0.0858 | 0.4821** |
| 100-seed | $r_p$ | 0.2224 | -0.1436 | -0.1085 | 0.0012 | 0.1175 | -0.0101 | 0.0637 | 0.0738 | -0.1232 | 0.2092 |
| weight (g) | $r_g$ | 0.2266 | -0.1570 | -0.1181 | 0.0070 | 0.1499 | -0.0147 | 0.0634 | 0.0767 | -0.1304 | 0.2289 |
| Harvest index | $r_p$ | 0.1813 | -0.2179 | 0.0690 | -0.1907 | -0.0893 | -0.1578 | 0.0278 | 0.0264 | -0.0218 | 0.4323* |
| | $r_g$ | 0.2071 | -0.2455 | 0.0635 | -0.2192 | -0.0996 | -0.1889 | 0.0238 | 0.0180 | -0.0226 | 0.4641* |
| SCMR at 40 | $r_p$ | 0.5813** | -0.2233 | -0.6287** | -0.1658 | 0.1340 | -0.0216 | 0.1856 | 0.2248 | -0.3539* | 0.3843* |
| DAS | $r_g$ | 0.7185** | -0.2737 | -0.7073** | -00.1525 | 0.1898 | -0.0233 | 0.2158 | 0.2635 | -0.4040* | 0.4707** |
| SCMR at 60 | $r_p$ | 1.0000 | -0.4672** | -0.3029 | -0.479** | -0.0024 | 0.0871 | 0.0932 | 0.1118 | -0.1248 | 0.3518* |
| DAS | $r_g$ | 1.0000 | -0.5365** | -0.3253 | -0.513** | -0.0307 | 0.1030 | 0.1035 | 0.1190 | -0.1369 | 0.4111* |
| LAI at 50 DAS | $r_p$ | | 1.0000 | -0.0352 | 0.2092 | 0.1582 | -0.0300 | 0.0083 | 0.0216 | 0.1546 | -0.2021 |
| | $r_g$ | | 1.0000 | -0.0343 | 0.2602 | 0.1763 | -0.0343 | 0.0160 | 0.0190 | 0.1619 | -0.2336 |
| SLA at 40 DAS | $r_p$ | | | 1.0000 | 0.0459 | -0.1704 | 0.0118 | -0.0335 | -0.0891 | 0.2859 | -0.1268 |
| | $r_g$ | | | 1.0000 | -0.0012 | -0.2090 | 0.0072 | -0.0337 | -0.1039 | 0.3055 | -0.1545 |
| SLA at 60 DAS | $r_p$ | | | | 1.0000 | 0.1388 | 0.1303 | -0.0141 | -0.0149 | -0.0464 | -0.0223 |
| | $r_g$ | | | | 1.0000 | 0.2264 | 0.1536 | -0.0168 | -0.0263 | -0.0693 | 0.0103 |
| Protein content | $r_p$ | | | | | 1.0000 | 0.0162 | -0.0448 | -0.0414 | -0.0467 | -0.1276 |
| | $r_g$ | | | | | 1.0000 | 0.0267 | -0.0339 | -0.0418 | -0.0582 | -0.1623 |
| Carbohydrate | $r_p$ | | | | | | 1.0000 | -0.0288 | -0.0576 | -0.2147 | 0.1825 |
| content | $r_g$ | | | | | | 1.0000 | -0.0268 | -0.0583 | -0.2321 | 0.1887 |
| Endosperm (%) | $r_p$ | | | | | | | 1.0000 | 0.9774** | -0.0621 | 0.1637 |
| | $r_g$ | | | | | | | 1.0000 | 0.9895** | -0.0630 | 0.1676 |
| Gum content | $r_p$ | | | | | | | | 1.0000 | -0.0924 | 0.2040 |
| (%) | $r_g$ | | | | | | | | 1.0000 | -0.0944 | 0.2066 |
| Viscosity | $r_p$ | | | | | | | | | 1.0000 | -0.3245 |
| | $r_g$ | | | | | | | | | 1.0000 | -0.3413* |
| Seed yield | $r_p$ | | | | | | | | | | 1.0000 |
| | $r_g$ | | | | | | | | | | 1.0000 |

(1977). Observations on days to 50% flowering and days to maturity were recorded on per plot basis. The data were pooled and standard statistical procedures were followed for estimating genetic parameters, phenotypic and genotypic coefficient of variation (Burton 1952), heritability and genetic advance (Johnson *et al.* 1955).

## Statistics

Analysis of variance for the above 21 quantitative characters revealed significant differences among the genotypes for all the characters (both at 1 and 5% significant levels). Average of three replication mean values was taken for each genotype for all the characters and the data was analyzed using INDOSTAT software.

## RESULTS AND DISCUSSION

A thorough understanding of the association of plant characters with yield and its components is essential for any crop improvement programme, since the final yield is the sum total of all effects of several component traits. Phenotypic and genotypic correlation co-efficients were computed in order to assess the direction and magnitude of association the individual component characters with the seed yield (**Table 1**).

In the present study, characters such as pods per plant, number of clusters per plant, number of branches per plant, number of seeds per pod, harvest index, SCMR at 40 DAS and SCMR at 60 DAS had a positive and significant association with seed yield per plant (**Table 1**). Further, a positive and significant association was also observed among these individual components excepting number of seeds per pod. This might be because of its negative association with the plant height. This was in unison with the findings of Henry *et al.* (1986), Shekhawat and Singhania (2004), Singh *et al.* (2005), Buttar *et al.* (2008) indicating a positive and significant association of number of pods per plant, number of branches per plant and number of clusters per plant with seed yield per plant. Shekhawat and Choudhary (2004) reported a positive and significant association of number of seeds per pod with seed yield. Similarly Saini *et al.* (2004) and Choudhary *et al.* (2004) reported a positive and significant association of harvest index with seed yield per plant.

One of the interesting aspects of the present investigation was the positive association of quality parameters like endosperm percentage, gum content and carbohydrate content with seed yield. This can be attributed to their positive association of these with the yield contributing characters such as pods per plant, clusters per plant and number of branches per plant. However, viscosity had negative and significant association with seed yield. Protein content had negative association with seed yield. So keeping in view of the above results it can be derived that simultaneous im-

**Table 2** Genotypic path-coefficients among seed yield and its components in guar.

| Character | Days to 50 % flowering | Days to maturity | Plant height (cm) | № of branches / plant | № of clusters / plant | № of pods / cluster | № of pods / plant | № of seeds per pod | 100-seed weight (g) | Harvest index | Total correlation with seed yield/ plant |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50 % flowering | **-0.0787** | -0.2657 | -0.1880 | -0.0760 | 0.0190 | 0.0362 | -0.0727 | -0.0125 | 0.0086 | -0.0123 | -0.2567 |
| Days to maturity | -0.0424 | **-0.4929** | 0.3590 | -0.0927 | 0.0298 | -0.0202 | -0.1633 | -0.0273 | 0.0022 | -0.0243 | -0.4349* |
| Plant height (cm) | -0.0275 | -0.3273 | **0.5400** | -0.0290 | -0.0011 | -0.0164 | -0.0158 | -0.0708 | -0.0091 | -0.0113 | -0.04140 |
| Number of branches / plant | 0.0309 | 0.2359 | -0.0800 | **0.1937** | -0.0654 | 0.0231 | 0.3302 | 0.0209 | -0.0016 | 0.0229 | 0.7590** |
| Number of clusters / plant | 0.0197 | 0.1935 | 0.0080 | 0.1669 | **-0.1758** | 0.0304 | 0.3567 | -0.0225 | -0.0064 | 0.0156 | 0.7567** |
| Number of pods / cluster | -0.0200 | 0.0697 | -0.0620 | 0.0314 | -0.0162 | **0.1426** | 0.2841 | -0.0456 | -0.0063 | 0.0058 | 0.4753** |
| Number of pods / plant | 0.0124 | 0.1741 | -0.0180 | 0.1383 | -0.0585 | 0.0876 | **0.4625** | -0.0275 | -0.0092 | 0.0348 | 0.8816** |
| Number of seeds per pod | -0.0055 | -0.0748 | 0.2120 | -0.0225 | -0.0095 | 0.0361 | 0.0707 | **0.1800** | -0.0188 | 0.0073 | 0.4821** |
| 100-seed weight (g) | 0.0178 | 0.0289 | 0.1290 | 0.0081 | -0.0128 | 0.0236 | 0.1126 | -0.0894 | **-0.0378** | 0.0100 | 0.2289 |
| Harvest index | 0.0100 | 0.01368 | -0.000 | 0.0507 | -0.0136 | 0.0095 | 0.1840 | -0.0150 | -0.0043 | **0.0876** | 0.4641* |
| SCMR at 40 DAS | 0.0430 | 0.2461 | -0.1740 | 0.1114 | -0.0384 | 0.0169 | 0.1924 | 0.0192 | -0.0107 | 0.0061 | 0.4707** |
| SCMR at 60 DAS | 0.0517 | 0.3266 | -0.2880 | 0.0834 | -0.0242 | 0.0338 | 0.1969 | 0.0092 | -0.0086 | 0.0181 | 0.4111* |
| LAI at 50 DAS | -0.0205 | -0.2130 | 0.2910 | -0.0373 | 0.0073 | -0.0602 | -0.1216 | 0.01213 | 0.0059 | -0.0215 | -0.2336 |
| SLA at 40 DAS ($cm^2/g$) | -0.0306 | -0.1870 | 0.0150 | -0.0773 | 0.0233 | 0.0272 | -0.0445 | -0.0081 | 0.0045 | 0.0056 | -0.1545 |
| SLA at 60 DAS ($cm^2/g$) | -0.0278 | -0.1678 | 0.2110 | 0.0011 | -0.0083 | 0.0016 | -0.0025 | -0.0020 | -0.0003 | -0.0192 | 0.0103 |
| Protein content (%) | -0.0128 | -0.0266 | 0.0440 | -0.0204 | 0.0073 | -0.0145 | -0.0466 | -0.0133 | -0.0057 | -0.0087 | -0.1623 |
| Carbohydrate content (% | 0.0216 | 0.0710 | 0.0210 | 0.0444 | -0.0241 | 0.0129 | 0.1243 | -0.0096 | 0.0006 | -0.0165 | 0.1887 |
| Endosperm (%) | 0.0113 | -0.0147 | 0.0210 | 0.0228 | -0.0068 | -0.0158 | 0.0591 | -0.0270 | -0.0024 | 0.0021 | 0.1676 |
| Gum content (%) | 0.0123 | -0.0124 | 0.0410 | 0.0310 | -0.0101 | -0.0119 | 0.0714 | -0.0283 | -0.0029 | 0.0016 | 0.2066 |
| Viscosity ($c.pa.s^{-1}$) | -0.0042 | 0.0101 | -0.0930 | -0.0629 | 0.0249 | -0.0268 | -0.1401 | -0.0154 | 0.0049 | -0.0020 | -0.3413* |

Residual effect genotypic = 0.1520
Diagonals: Direct effects
Off-diagonals: Indirect effects
*,**: Significant at 5% and 1%, respectively

**Table 2** (Cont.)

| Character | SCMR at 40 DAS | SCMR at 60 DAS | LAI at 50 DAS | SLA at 40 DAS | SLA at 60 DAS | Protein content | Carbo-hydrate content | Endo-sperm | Gum content | Viscosity | Total correlation with seed yield/ plant |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Days to 50 % flowering | -0.2773 | 0.1738 | -0.0158 | 0.1462 | 0.0017 | -0.0125 | 0.0023 | 0.0165 | -0.0258 | 0.0016 | -0.2567 |
| Days to maturity | -0.2537 | 0.1753 | -0.0262 | 0.1429 | 0.0017 | -0.0041 | 0.0012 | -0.0034 | 0.0041 | -0.0006 | -0.4349* |
| Plant height (cm) | -0.1643 | 0.1413 | -0.0326 | 0.0106 | 0.0019 | -0.0063 | -0.0003 | -0.0045 | 0.0128 | -0.0052 | -0.04140 |
| Number of branches / plant | 0.2922 | -0.1139 | 0.0117 | -0.1502 | 0.0000 | 0.0081 | -0.0019 | -0.0136 | 0.0265 | -0.0097 | 0.7590** |
| Number of clusters / plant | 0.2574 | -0.0844 | 0.0058 | -0.1156 | 0.0005 | 0.0074 | -0.0026 | -0.0103 | 0.0221 | -0.0098 | 0.7567** |
| Number of pods / cluster | 0.0602 | -0.0627 | 0.0256 | 0.0720 | 0.0001 | 0.0078 | -0.0007 | 0.0128 | -0.0139 | -0.0056 | 0.4753** |
| Number of pods / plant | 0.2113 | -0.1126 | 0.0159 | -0.0362 | 0.0000 | 0.0077 | -0.0022 | -0.0147 | 0.0255 | -0.0091 | 0.8816** |
| Number of seeds per pod | 0.0543 | 0.0136 | 0.0041 | 0.0170 | 0.0001 | -0.0057 | -0.0004 | -0.0173 | 0.026 | 0.0026 | 0.4821** |
| 100-seed weight (g) | 0.1433 | -0.0599 | 0.0095 | -0.0445 | 0.0000 | -0.0115 | 0.0001 | -0.0073 | 0.0127 | -0.0039 | 0.2289 |
| Harvest index | 0.0352 | -0.0548 | 0.0149 | 0.0239 | -0.0011 | 0.0077 | 0.0016 | -0.0027 | 0.0030 | -0.0007 | 0.4641* |
| SCMR at 40 DAS | **0.5081** | -0.1901 | 0.0166 | -0.2663 | -0.0008 | -0.0146 | 0.0002 | -0.0249 | 0.04360 | -0.0121 | 0.4707** |
| SCMR at 60 DAS | 0.3651 | **-0.2645** | 0.0325 | -0.1225 | -0.0025 | 0.0024 | -0.0008 | -0.0119 | 0.0197 | -0.0041 | 0.4111* |
| LAI at 50 DAS | -0.1391 | 0.1419 | **-0.0605** | -0.0129 | 0.0013 | -0.0136 | 0.0003 | -0.0018 | 0.0031 | 0.0049 | -0.2336 |
| SLA at 40 DAS ($cm^2/g$) | -0.3594 | 0.0861 | 0.0021 | **0.3766** | 0.0000 | 0.0161 | -0.0001 | 0.0039 | -0.0172 | 0.0920 | -0.1545 |
| SLA at 60 DAS ($cm^2/g$) | -0.0775 | 0.1357 | -0.0158 | -0.0004 | **0.0049** | -0.0174 | -0.0013 | 0.0019 | -0.0043 | -0.0021 | 0.0103 |
| Protein content (%) | 0.0964 | 0.0081 | -0.0107 | -0.0787 | 0.0011 | **-0.0769** | -0.0002 | 0.0039 | -0.0069 | -0.0017 | -0.1623 |
| Carbohydrate content (% | -0.0118 | -0.0272 | 0.0021 | 0.0027 | 0.0008 | -0.0021 | **-0.0082** | 0.0031 | -0.0096 | -0.0070 | 0.1887 |
| Endosperm (%) | 0.1097 | -0.0274 | -0.001 | -0.0127 | -0.0001 | 0.0026 | 0.0002 | **0.1530** | 0.1637 | -0.0019 | 0.1676 |
| Gum content (%) | 0.1339 | -0.0315 | -0.0012 | -0.0391 | -0.0001 | 0.0032 | 0.0005 | -0.1141 | **0.1654** | -0.0028 | 0.2066 |
| Viscosity ($c.pa.s^{-1}$) | -0.2053 | 0.0362 | -0.0098 | 0.1150 | -0.0003 | 0.0045 | 0.0019 | 0.0073 | -0.0156 | **0.0300** | -0.3413* |

Residual effect genotypic = 0.1520
Diagonals: Direct effects
Off-diagonals: Indirect effects
*,**: Significant at 5% and 1%, respectively

provement for seed yield and quality parameters are possible by compromising on viscosity and protein content.

Path coefficient analysis helps in understanding the magnitude of direct and indirect contribution of each trait on a dependent variable like seed yield (**Table 2**). In the present investigation, plant height exerted high positive direct effect on seed yield per plant. However, it had negative association with seed yield. This is because with increase in plant height later formed pods will have immature seeds and when harvested results in more number of blackened and shriveled seeds thereby reducing the quality. This was in agreement with the findings of Choudhary *et al.* (2001).

Chlorophyll meter reading at 40 DAS and number of pods per plant had high positive direct effect on seed yield per plant and could be taken as major components for improvement of seed yield. Singh *et al.* (2005) reported that pods per plant had highest positive direct effect on yield. Moderate positive direct effects were exerted by SLA at 40 DAS on seed yield. However, low positive direct effects were exhibited by number of branches per plant, number of seeds per pod, gum content, number of pods per cluster, endosperm percentage, harvest index, viscosity and SLA at 60 DAS on seed yield.

In contrast, days to maturity, SCMR at 60 DAS, number of clusters per plant, days to 50% flowering, protein content, leaf area index at 50 DAS, 100-seed weight and carbohydrate content exhibited negative direct effect on seed yield. Similar kind of low negative direct effects of days to 50% flowering and 100-seed weight on seed yield were reported by Choudhary *et al*. (2001).

Selection of genotypes based on SCMR at 40 DAS, as selection criterion would be helpful in improving seed yield as they exhibited direct positive effect. Further molecular characterization for assessment of heat shock proteins using the genotypes which exhibited high SCMR will aid in indirect selection for seed yield using this trait Quality traits like gum content, carbohydrate content and endosperm percentage were positively associated with seed yield. Hence, it is easy to combine simultaneous selection of these quality traits with seed yield in selection of elite genotypes with present set of experimental material. From this it is clear that selection could be extended for accomplishing improvement in seed yield potential as well as gum content.

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