



Research Paper

## Character association and path analysis for yield and its attributing traits among urdbean landraces

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### ABSTRACT

In the present study, character association and path analysis were studied among 23 urdbean genotypes for 11 quantitative traits. Correlation analysis divulged that seed yield/plant proclaimed a significant positive relationship between branches/plant, biological yield/plant, pods/plant, and pod length at both genotypic and phenotypic levels and also showed a direct effect on yield. Biological yield/plant, branches/plant and pods/plant had the most beneficial direct and indirect influences on the overall relationship between yield and other component attributes, indicating the high inter-dependent interaction among these traits. Therefore, these characteristics could be considered as optimum selection indices on a priority basis, which would be remarkable for improving genotype efficiency during genetic improvement.

**Key words:** Correlations, Path analysis, Traits, Urdbean, Genotypes

### INTRODUCTION

Urdbean (*Vigna mungo* (L.) Hepper, 2n=2x=22), popularly known as blackgram, black lentil, or black matpe bean, is a tropical pulse crop extensively grown in the Indian sub-continent and predominantly used for human consumption, fodder and soil-enriching green manure. Urdbean is a substantial source of dietary protein among the population of South Asia. It is widely grown in Afghanistan, Bangladesh, India, Pakistan, Nepal, and Myanmar whereas, Thailand, Australia, and other Asian as well as South Pacific regions to a limited extent (Patial *et al.* 2020). It has a brief growing season and is cultivated in various parts of India during the summer, rainy (*Kharif*), and winter (*Rabi*) seasons. In four agro-climatic zones of Himachal Pradesh, various types of landraces are cultivated either as a sole crop or intercrop with maize/orchard in heterogeneous growth conditions.

Besides that, this crop is still typically grown on poor soils and rainfed conditions has a narrow genetic base, non-availability of high-yielding cultivars, and is vulnerable to various biotic and abiotic stresses, leading to low yield. Thus improvement in yield is the prime objective of any breeder in this crop. The presence of genetic diversity and the degree of association between yield and its related traits in the crop are the primary determinants of achieving high yield. The choice of potential genotypes is

critical in crop breeding (Soharu *et al.* 2022). Being a quantitative trait, the direct selection for yield is not beneficial for the production of better genotypes, as yield is influenced by multiple component traits. As a result, the correlation study provided insights into the significance of several characteristics to the seed yield. It provides an estimate of the association between characteristics as well as the extent to which different characters are associated with seed yield, which leads inevitably to yield enhancement in a brief period (Priya *et al.* 2018). Its assessment allows for the rejection of variables with slight or no significance during selection. Whenever there is a positive association between key yield attributes, breeding approaches are quite efficient; nevertheless, if there is a negative correlation, selection gets extremely challenging. Path coefficient also known as cause and effect is a statistical approach for categorizing reported correlation coefficients as direct or indirect impacts on the dependent variable by independent variables. Direct effect correlations represent accurate and perfect relationships and such traits can be immediately addressed to boost yield (Ahmed and Belwal 2020). Thus, the present investigation sought to create urdbean genotypes with greater genetic variability, flexibility, and high production by investigating the essence and magnitude of the correlation between yield and related attributes for effective selection in crop improvement programme(s). Taking that into consideration, the present study was aimed to

determine character association and path analysis among 23 urdbean genotypes for yield and yield contributing traits.

## MATERIALS AND METHODS

Inn the present investigation, 20 landraces with three checks namely Him Mash-1, HPBU-111 and Palampur-93 procured from different urdbean growing regions (Chamba, Kangra, Kullu, Mandi, Sirmour, Bilaspur and Kinnour) and maintained at CSK HPKV, Himachal Pradesh, India (Table 1). During *kharif* 2021, field trials were conducted in two distinct locations: (i) KVK Berthin situated at 31°2'N/76°3'E having medium-deep to deep, loamy-skeletal soils, average annual temperature 18.9 °C, rainfall 1074 mm, and Palampur situated at 32°4'N/76°3'E having grey-brown podzolic soils, the average annual temperature of 16.8 °Cm and rainfall 1578 mm. The investigation was carried out in randomized block design (RBD) with two replications at each location. The plot size involved two rows/genotype having plant to plant and row to row spacing of 10 and 30 cm, respectively. Standard agronomic packages and practices were followed to raise crops. In each experimental plot, observations were recorded on five randomly selected plants in each plot for yield and its attributing traits including plant height (cm), branches/plant (no.), pods/plant (no.), pod length (cm), biological yield/plant (g), harvest index (%), 100-seed weight (g), yield/plant (g), seeds/pod (no.), while for traits like days to 50% flowering and days to 75% maturity was done on plot basis.

**Table 1.** List of genotypes used in study

| Sr. No. | Genotype     | Place                                                                            | District | Latitude / Longitude |
|---------|--------------|----------------------------------------------------------------------------------|----------|----------------------|
| 1       | Chamba-1     | Chamba                                                                           | Chamba   | 32.5 ° N / 76.1 ° E  |
| 2       | Sirmour-1    | Renuka                                                                           | Sirmour  | 30.6° N/ 77.4° E     |
| 3       | Kangra-1     | Nagrota Suriyan                                                                  | Kangra   | 32.0° N/ 76.0° E     |
| 4       | Sirmour-2    | Shillai                                                                          | Sirmour  | 30.6° N/ 77.7° E     |
| 5       | Kangra-2     | Village Mainzha                                                                  | Kangra   | 32.1° N/ 76.5° E     |
| 6       | Kullu-1      | Kullu                                                                            | Kullu    | 31.9° N / 77.1° E    |
| 7       | Kullu-2      | Kullu                                                                            | Kullu    | 31.8° N / 77.1° E    |
| 8       | Chamba-2     | Chamba                                                                           | Chamba   | 32.5 ° N / 76.1 ° E  |
| 9       | Mandi-1      | Barot-valley                                                                     | Mandi    | 32.0° N/ 76.8° E     |
| 10      | Kullu-3      | Kullu                                                                            | Kullu    | 31.9° N / 77.1° E    |
| 11      | Kullu-4      | Haripur                                                                          | Kullu    | 32.1° N/ 77.1° E     |
| 12      | Chamba-3     | Village Thalla                                                                   | Chamba   | 35.5° N / 76.1° E    |
| 13      | Chamba-4     | Village Deoki                                                                    | Chamba   | 32.4° N / 76.4° E    |
| 14      | Chamba-5     | Gatiyala Di Dhar                                                                 | Chamba   | 32.4° N / 76.0° E    |
| 15      | Chamba-6     | Village Sodi                                                                     | Chamba   | 32.4° N / 76.5° E    |
| 16      | Kangra-3     | Nagrota Bagwan                                                                   | Kangra   | 32.1° N/ 76.3° E     |
| 17      | Mandi-2      | Karsog                                                                           | Mandi    | 31.3° N/ 77.2° E     |
| 18      | Chamba-7     | Bharmour                                                                         | Chamba   | 32.4° N / 76.5° E    |
| 19      | Bilaspur-1   | Sadar                                                                            | Bilaspur | 31.3° N / 76.6° E    |
| 20      | Chamba-8     | Bharmour                                                                         | Chamba   | 32.4° N / 76.5° E    |
| 21      | Him Mash-1©  | Advanced line selection from DPU-91-5 × Mash-338                                 |          |                      |
| 22      | Palampur-93© | Pure line selection from local material of Himachal Pradesh by CSKHPKV, Palampur |          |                      |
| 23      | HPBU-111©    | Pure line selection from local material of Himachal Pradesh by CSKHPKV, Palampur |          |                      |

Statistical analysis was carried out to compute the correlation coefficient as well as the path coefficient. Genotypic and phenotypic correlation between quantitative traits were estimated according to Al Jibouri *et al.* (1958), whilst path coefficient analysis by the method suggested by Dewey and Lu (1959). The OPSTAT program created by CCS HAU, Hisar, India, was used to generate simple correlation coefficients and path coefficients (Sheoran *et al.* 1998).

## RESULTS AND DISCUSSION

Selection based on an in-depth comprehension of the strength and direction of the relationship between yield and its attributes is essential, to determine the key traits that can be implemented to improve crops through an appropriate breeding strategy. The pooled analysis of variance revealed significant variability among the genotypes under investigation at both the locations, while for the eight characters *viz.*, days to 50% flowering, plant height, days to maturity, branches/plant, biological yield/plant, pod length, 100-seed weight and yield/plant for interaction (G×E) (Table 5, Soharu *et al.* 2022). The results of mean performance for yield (Table 2) revealed that the genotypes Sirmour-1, Kangra-1, and Chamba-6 are the best, as they possessed more yield than the checks. Therefore, their performance can be re-evaluated in further yield trials and can be released as a variety or can be used as parent(s) in blackgram breeding programs. The magnitude of the phenotypic coefficient of variance is a little higher than the genotypic coefficient of variance, indicating the presence of a correlation between them (Table 6, Soharu *et al.* 2022). High value for PCV, GCV (61.22%, 59.95%), heritability (95.89%) coupled with genetic advance as percent of mean (120.94) was observed for harvest index trailed by yield per plant (PCV:26.42%, GCV: 24.33, heritability: 84.83% and genetic advance as percent of mean: 46.16). Thus, suggesting the effective selection for the above traits

### Correlation analysis

Correlation coefficients explore the relationship between yield and its contributing traits. It shows that choosing one trait leads to the advancement of all positively associated attributes. Assessments of phenotypic and genotypic correlation coefficients for various traits were estimated under this investigation and are given in Figure 1. The assessment of correlation at Berthin (Fig. 1A) showed that days to 50% flowering was significantly and positively correlated with

**Table 2.** Mean performance (pooled) of the blackgram genotypes for yield and component traits

| Genotypes   | DFFL        | DSFM        | PH          | BPP        | BYPP        | HI          | SPP        | PP          | PL         | HSW        | YPP        |
|-------------|-------------|-------------|-------------|------------|-------------|-------------|------------|-------------|------------|------------|------------|
| Chamba-1    | 48.0        | 81.0        | 54.6        | 4.0        | 25.5        | 20.0        | 6.0        | 24.0        | 4.8        | 4.3        | 4.6        |
| Sirmour-1   | 45.0        | 79.0        | 31.6        | 4.0        | 27.0        | 21.1        | 5.0        | 26.0        | 4.6        | 3.7        | 5.1        |
| Kangra-1    | 46.0        | 79.0        | 79.6        | 5.0        | 45.1        | 12.1        | 5.0        | 26.4        | 4.8        | 4.0        | 5.2        |
| Sirmour-2   | 52.0        | 79.0        | 57.4        | 5.0        | 46.2        | 14.1        | 6.0        | 28.6        | 4.9        | 4.2        | 4.6        |
| Kangra-2    | 50.0        | 79.0        | 68.6        | 4.0        | 29.6        | 23.8        | 4.0        | 23.8        | 4.4        | 3.5        | 3.8        |
| Kullu-1     | 48.0        | 80.0        | 56.2        | 5.0        | 28.0        | 20.3        | 5.0        | 24.3        | 4.7        | 3.6        | 4.0        |
| Kullu-2     | 46.0        | 81.0        | 52.6        | 5.0        | 29.1        | 21.2        | 6.0        | 20.6        | 4.6        | 3.5        | 3.9        |
| Chamba-2    | 43.0        | 79.0        | 51.7        | 4.0        | 17.4        | 21.3        | 6.0        | 16.0        | 4.7        | 3.5        | 2.4        |
| Mandi-1     | 42.0        | 78.0        | 54.4        | 5.0        | 15.9        | 25.3        | 6.0        | 19.9        | 4.7        | 3.8        | 3.2        |
| Kullu-3     | 48.0        | 81.0        | 63.5        | 4.0        | 18.0        | 22.8        | 6.0        | 13.4        | 4.7        | 4.0        | 2.3        |
| Kullu-4     | 51.0        | 81.0        | 67.8        | 4.0        | 22.5        | 18.5        | 6.0        | 21.5        | 4.7        | 3.6        | 3.6        |
| Chamba-3    | 47.0        | 81.0        | 61.2        | 5.0        | 23.2        | 17.0        | 5.0        | 29.1        | 4.6        | 3.8        | 4.1        |
| Chamba-4    | 49.0        | 80.0        | 62.0        | 5.0        | 23.2        | 18.0        | 6.0        | 21.0        | 4.7        | 3.3        | 3.9        |
| Chamba-5    | 42.0        | 77.0        | 55.9        | 6.0        | 25.8        | 26.3        | 5.0        | 21.3        | 5.2        | 3.3        | 4.8        |
| Chamba-6    | 49.0        | 79.0        | 66.6        | 6.0        | 41.9        | 20.7        | 6.0        | 23.4        | 4.7        | 3.7        | 6.1        |
| Kinnaur-1*  | -           | -           | -           | -          | -           | -           | -          | -           | -          | -          | -          |
| Kangra-3    | 50.0        | 77.0        | 62.8        | 4.0        | 13.4        | 23.9        | 6.0        | 20.2        | 4.7        | 3.4        | 2.4        |
| Mandi-2     | 51.0        | 80.0        | 57.7        | 5.0        | 19.5        | 26.5        | 6.0        | 22.0        | 4.6        | 3.5        | 3.8        |
| Chamba-7    | 47.0        | 77.0        | 50.5        | 5.0        | 28.2        | 26.8        | 6.0        | 18.7        | 4.7        | 3.6        | 4.8        |
| Bilaspur-1  | 50.0        | 84.0        | 59.7        | 3.0        | 16.2        | 40.8        | 5.0        | 17.4        | 4.6        | 3.9        | 2.9        |
| Chamba-8    | 47.0        | 79.0        | 50.6        | 4.0        | 19.4        | 20.0        | 6.0        | 18.9        | 4.7        | 3.5        | 3.9        |
| Him Mash-1  | 43.0        | 80.0        | 42.8        | 5.0        | 13.0        | 37.9        | 6.0        | 18.5        | 4.6        | 3.7        | 3.4        |
| Palampur-93 | 45.0        | 79.0        | 42.5        | 4.0        | 12.7        | 30.4        | 5.0        | 17.5        | 4.5        | 4.3        | 3.0        |
| HPBU-111    | 50.0        | 80.0        | 51.5        | 4.0        | 27.3        | 17.6        | 6.0        | 22.8        | 4.9        | 3.6        | 4.1        |
| <b>Mean</b> | <b>47.0</b> | <b>78.0</b> | <b>57.0</b> | <b>4.0</b> | <b>24.7</b> | <b>22.9</b> | <b>6.0</b> | <b>21.5</b> | <b>4.7</b> | <b>3.7</b> | <b>3.9</b> |
| CD (p=0.05) | 1.2         | 1.4         | 11.6        | 0.5        | 5.7         | 3.7         | 0.8        | 6.7         | 0.3        | 0.2        | 0.8        |
| SE(m)       | 0.4         | 0.5         | 3.9         | 1.8        | 1.9         | 1.3         | 0.3        | 2.3         | 0.1        | 0.1        | 0.3        |
| SE(d)       | 0.6         | 0.7         | 5.6         | 0.2        | 2.7         | 1.8         | 0.4        | 3.2         | 0.2        | 0.1        | 0.4        |
| C.V.        | 1.2         | 0.9         | 9.8         | 5.6        | 11.2        | 13.9        | 6.8        | 15.0        | 3.3        | 2.9        | 10.3       |

\*Does not flower in both the locations

**Abbreviations:** DFFL= Days to 50 % flowering; DSFM= Days to 75% maturity; PH= Plant height; BPP= Branches / plant; BYP= Biological yield / plant; HI= Harvest index; SPP= Seeds / pod; PP= Pods / plant; PL= Pod length; HSW= 100-seed weight; YPP= Yield / plant

harvest index while, it had a significantly negative association with plant height, branches/plant, biological yield/plant, pods/plant, pod length, 100-seed weight and yield/plant only at the genotypic level. Days to 75% maturity also exhibited a significant positive inter-relationship with harvest index and 100-seed weight. Whereas, it showed a significant negative inter-relationship only with pods/plant genotypically. Plant height had a substantial and positive association with biological yield/plant and a significant negative correlation with harvest index at both levels. Branches/plant exhibited positive as well as significant relationships phenotypically as well as genotypically with biological yield/plant, pods/plant and yield/plant, similarly with pod length only at the genotypic level. Biological yield/plant had a substantial and positive interaction with pod length (genotypically), pods/plant, yield/plant and had a significant

negative relationship with harvest index at both levels. Seeds/pod were significant and positively associated with pod length only at the genotypic level. Pods/plant manifested a significant positive correlation with only yield/plant phenotypically as well as genotypically, while with 100-seed weight only at the genotypic level. Pod length showed a significant positive association with yield/plant at the genotypic level only. Grain yield exhibited a substantial positive association with branches/plant, biological yield/plant, pods/plant, seeds/pod, and pod length demonstrating that selection through these attributes might be beneficial.

In Palampur (Fig. 1B), correlation revealed that at both levels days to 50% flowering were significantly as well as strongly associated with days to 75% maturity; on the other hand with yield/plant and branches/plant it showed positive and negative association respectively, only at genotypic

level. Days to 75% maturity exhibited a significant positive correlation to 100-seed weight at both levels, whilst having a significant negative association with branches/plant only phenotypically. Plant height was strongly related to branches/plant, biological yield/plant (0.498), pods/plant, pod length, and yield/plant, as well as negatively correlated to harvest index at both levels, while positively correlated with 100-seed weight only at the genotypic level. Branches/plant indicated significant and positive correlation with harvest index, whereas it manifested significant negative inter-relation with seeds/pod, pods/plant, and yield/plant at the genotypic level only. Biological yield/plant proclaimed a substantial positive relationship with seeds/pod (genotypically), pods/plant, and yield/plant, but it had a negative association with harvest index both at genotypically and phenotypically. At both levels, the harvest index had a strong but negative association with seeds/pod, pods/plant, and yield/plant. Seeds/pod demonstrated a significant and positive association with yield/plant phenotypically and genotypically but with pods/plant at the genotypic level only. The number of pods/plant has a significant positive association with yield/plant at both levels but with pod length only at the phenotypic level. Pod length was found to have a substantial positive relationship with yield/plant phenotypically. Grain yield demonstrated a significant positive relationship with days to 50% flowering, plant height, biological yield/plant, seeds/pod, pods/plant, and pod length, referring to favorable selection for these attributes. As a result of the foregoing findings, a combined study (Figure 1C) revealed that grain yield was found to have a strong positive relationship with branches/plant, biological yield/plant, pods/plant, and pod length, implying that selection based on these characteristics could be advantageous. So, to enhance grain yield, emphasis needs to be placed on the selection of these traits. Suvarchala *et al.* (2010) produced similar trends for biological yield/plant, number of branches/plant, seeds/pod, and pod length. Bharti *et al.* (2013) identified a significant positive relationship between variables such as the number of pods/cluster, the number of seeds/pod, and the biological yield/plant. Punia *et al.* (2014) and Parveen *et al.* (2011) discovered similar inter-relationships for pods/plant. Ahmed *et al.* (2020) for pods/plant and number of branches/plant in mungbean (*Vigna radiata*), while for cluster/plant, number of pods/cluster, number of pods/plant, 100-seed weight, biological yield/plant, and harvest index by Khan *et al.* (2020).

### Path analysis

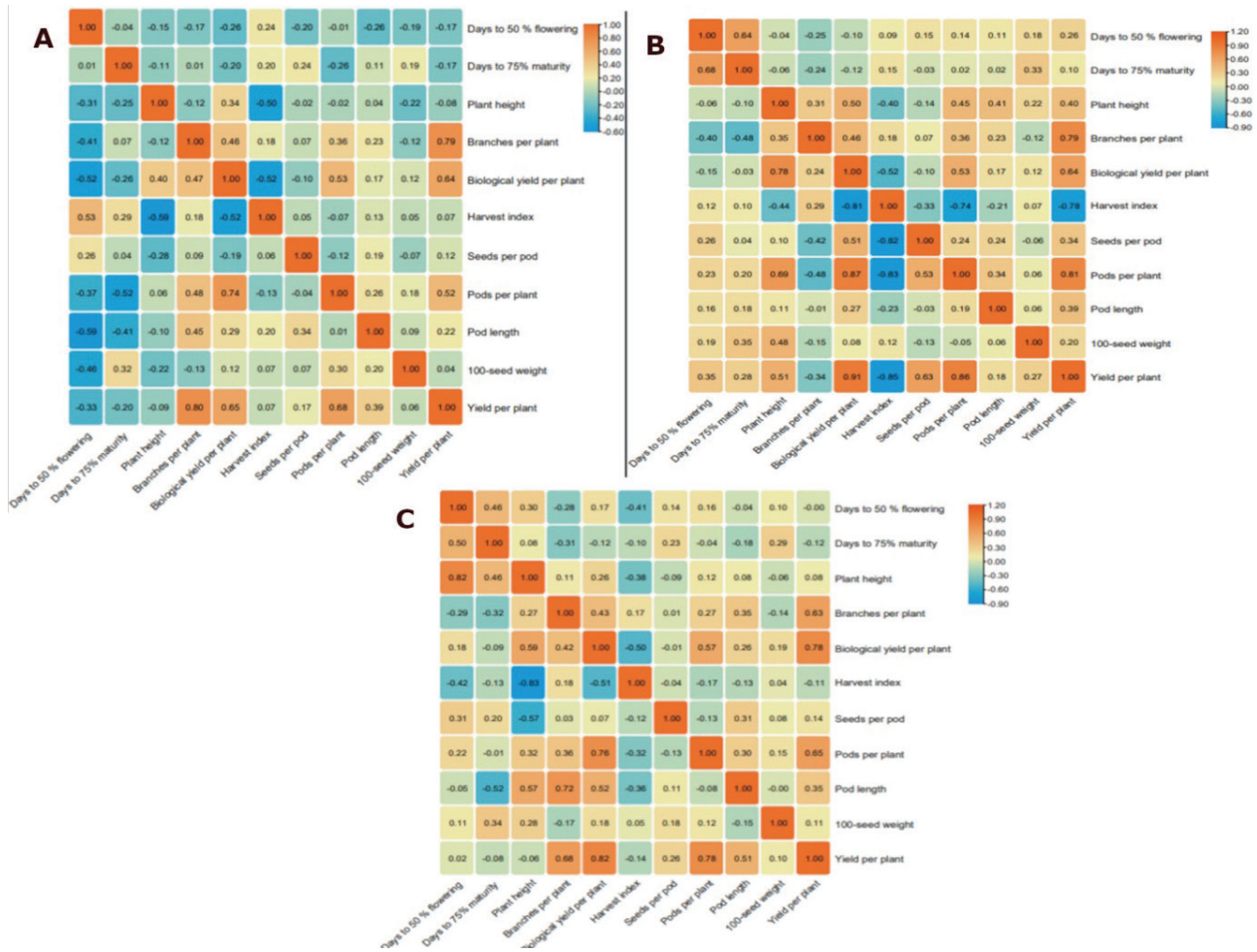
Correlation studies do not provide an accurate depiction of the proportional relevance of the direct and indirect influence of each component trait because these estimations only provide nature and magnitude, not cause. This is so because the characteristics that are associated with one another do not exist independently.

In such cases, path coefficient analysis (Dewey and Lu 1959) can effectively divide the correlation into direct and indirect effects of a particular causal factor. It can be used to measure the degree of correlation between yield and its component traits, as well as to investigate specific factors that contribute to a correlation. The values of path analysis at both phenotypic and genotypic levels are presented in Table 3.

The estimates of phenotypic and genotypic path revealed that characters like biological yield/plant ( $p=67$ ,  $g=0.85$ ), branches/plant ( $p=0.23$ ,  $g=0.55$ ), and pods/plant ( $p=0.30$ ), proclaimed significant positive direct effect on grain yield/plant. In conclusion, direct selection for branches/plant, pods/plant, and biological yield/plant can enhance grain yield. At Berthin the association was observed only at the genotypic level of characters like days to 50% flowering, days to 75% maturity, plant height, and pod length, whereas, days to 50% flowering showed a negative correlation with grain yield was mainly due to its negative indirect effect *via* branches/plant, biological yield/plant, pods/plant and pod length. On the same token, days to 75% maturity showed a negative correlation with grain yield through biological yield/plant, pods/plant, pod, and 100-seed weight. The plant height showed a negative association with grain yield through its direct negative effect and indirectly *via* days to 50% flowering, days to 75% maturity, branches/plant, harvest index, seeds/pod, and pod length. Similarly, pod length showed a significant positive association through its direct effect and indirectly *via* branches/plant, biological yield/plant, and seeds/pod with grain yield/plant.

The significant and positive association of branches/plant with grain yield resulted mainly due to direct effect and indirectly through biological yield/plant, harvest index, and pods. The significant and positive association of branches/plant with grain yield resulted mainly due to its direct effect and indirectly through biological yield/plant, harvest index and pods/plant at phenotypic level. While, at the genotypic level due to its direct effect





**Fig. 1.** Correlograph of phenotypic (up/) and genotypic (lower) correlation coefficient among various yield and morphological traits in urbean genotypes at Berthin (A), Palampur (B) and Pooled over locations (C)

followed by biological yield/plant, pods/plant and pod length.

Furthermore, the phenotypic path of biological yield/plant exhibited a significant positive correlation due to its direct effect as well as indirectly by pods/plant, days to 75% maturity, and branches/plant, on the other hand, the genotypic path was due to its direct effect followed by pods/plant and branches/plant. Likewise, the significantly positive association of pods/plant with grain yield at the phenotypic level occurred partly due to direct and chiefly due to its indirect effects with traits like biological yield/plant, branches/plant, and days to 75% maturity whereas, it was mainly due to its to direct as well as its indirect effects with biological yield/plant and branches/plant at the genotypic level.

At Palampur, the significant positive association of days to 50% flowering with grain yield

was observed at the genotypic level mainly due to its indirect effect via seeds/pod, harvest index, pods/plant, days to 75% flowering, and branches/plant. At the phenotypic level, a significant positive association between plant height with grain yield mainly occurred through its indirect effects like branches/plant, biological yield/plant, harvest index, pods/plant, pod length, and 100-seed weight, whereas at genotypic level association with grain yield chiefly through its direct effect as well as indirectly through biological yield/plant, pods/plant, seeds pod and days to 50% flowering. The phenotypic path of Biological yield/plant showed a significant and positive correlation with grain yield due to its direct effect and indirectly *via* harvest index, pods/plant, pod length, 100-seed weight, and branches/plant, whilst, genotypically it occurred due to its direct effect and *via* seeds/pod, pods/plant, plant height, days to 50% flowering. On the other hand, the phenotypic path of harvest

**Table 3.** Phenotypic (P) and genotypic (G) path coefficient analysis showing direct and indirect effects of different characters on seed yield per plant

| Traits | Location | Level | DFFL          | DSFM          | PH            | BPP           | BYPP         | HI            | SPP          | PP            | PL            | HSW           | YPP      |
|--------|----------|-------|---------------|---------------|---------------|---------------|--------------|---------------|--------------|---------------|---------------|---------------|----------|
| DFFL   | Berthin  | P     | <b>-0.002</b> | 0.005         | 0.014         | -0.076        | -0.146       | 0.065         | -0.038       | -0.001        | 0.012         | -0.006        | -0.172   |
|        |          | G     | <b>0.092</b>  | 0.000         | 0.024         | -0.171        | -0.171       | 0.034         | 0.032        | -0.124        | -0.073        | 0.026         | -0.330*  |
|        | Palampur | P     | <b>0.258</b>  | -0.019        | 0.005         | -0.024        | -0.014       | -0.044        | 0.005        | 0.038         | 0.015         | 0.037         | 0.256    |
|        |          | G     | <b>-2.334</b> | 0.493         | -0.084        | 0.334         | -0.147       | 0.721         | 1.063        | 0.423         | -0.031        | -0.091        | 0.346*   |
|        | Pooled   | P     | <b>-0.041</b> | 0.027         | -0.014        | -0.066        | 0.113        | -0.090        | 0.027        | 0.047         | 0.001         | -0.007        | -0.004   |
|        |          | G     | <b>-0.139</b> | -0.086        | 0.138         | -0.159        | 0.157        | -0.037        | 0.136        | -0.008        | 0.028         | -0.010        | 0.020    |
| DSFM   | Berthin  | P     | 0.000         | <b>-0.150</b> | 0.010         | 0.003         | -0.112       | 0.053         | 0.044        | -0.017        | -0.005        | 0.006         | -0.168   |
|        |          | G     | 0.001         | <b>0.052</b>  | 0.020         | 0.030         | -0.087       | 0.019         | 0.006        | -0.174        | -0.051        | -0.018        | -0.202   |
|        | Palampur | P     | 0.164         | <b>-0.031</b> | 0.007         | -0.023        | -0.017       | -0.075        | -0.001       | 0.006         | 0.002         | 0.066         | 0.099    |
|        |          | G     | -1.590        | <b>0.723</b>  | -0.133        | 0.401         | -0.032       | 0.568         | 0.175        | 0.365         | -0.034        | -0.164        | 0.280    |
|        | Pooled   | P     | -0.019        | <b>0.059</b>  | -0.004        | -0.073        | -0.080       | -0.023        | 0.044        | -0.012        | 0.004         | -0.020        | -0.124   |
|        |          | G     | -0.069        | <b>-0.173</b> | 0.077         | -0.173        | -0.075       | -0.012        | 0.089        | 0.000         | 0.292         | -0.032        | -0.076   |
| PH     | Berthin  | P     | 0.000         | 0.016         | <b>-0.091</b> | -0.054        | 0.195        | -0.135        | -0.003       | -0.001        | -0.002        | -0.007        | -0.082   |
|        |          | G     | -0.028        | -0.013        | <b>-0.080</b> | -0.051        | 0.132        | -0.038        | -0.034       | 0.019         | -0.012        | 0.012         | -0.092   |
|        | Palampur | P     | -0.011        | 0.002         | <b>-0.114</b> | 0.030         | 0.072        | 0.199         | -0.004       | 0.123         | 0.055         | 0.044         | 0.396**  |
|        |          | G     | 0.146         | -0.071        | <b>1.345</b>  | -0.292        | 0.772        | -2.620        | 0.393        | 1.273         | -0.208        | -0.225        | 0.514**  |
|        | Pooled   | P     | -0.012        | 0.005         | <b>-0.048</b> | 0.025         | 0.171        | -0.083        | -0.017       | 0.037         | -0.002        | 0.004         | 0.079    |
|        |          | G     | -0.114        | -0.079        | <b>0.169</b>  | 0.149         | 0.500        | -0.073        | -0.253       | -0.012        | -0.319        | -0.026        | -0.057   |
| BPP    | Berthin  | P     | 0.000         | -0.001        | 0.011         | <b>0.446</b>  | 0.263        | 0.048         | 0.013        | 0.023         | -0.011        | -0.004        | 0.789**  |
|        |          | G     | -0.037        | 0.004         | 0.010         | <b>0.422</b>  | 0.153        | 0.012         | 0.011        | 0.160         | 0.055         | 0.007         | 0.796**  |
|        | Palampur | P     | -0.065        | 0.007         | -0.036        | <b>0.097</b>  | 0.038        | -0.028        | -0.006       | 0.025         | 0.036         | -0.008        | 0.060    |
|        |          | G     | 0.925         | -0.344        | 0.466         | <b>-0.842</b> | 0.239        | 1.734         | -1.709       | -0.880        | 0.003         | 0.070         | -0.338*  |
|        | Pooled   | P     | 0.012         | -0.018        | -0.005        | <b>0.234</b>  | 0.286        | 0.037         | 0.001        | 0.081         | -0.007        | 0.010         | 0.630**  |
|        |          | G     | 0.040         | 0.054         | 0.046         | <b>0.551</b>  | 0.359        | 0.016         | 0.015        | -0.013        | -0.406        | 0.016         | 0.677**  |
| BYPP   | Berthin  | P     | 0.000         | 0.030         | -0.031        | 0.206         | <b>0.568</b> | -0.141        | -0.019       | 0.034         | -0.008        | 0.004         | 0.643**  |
|        |          | G     | -0.048        | -0.014        | -0.032        | 0.197         | <b>0.328</b> | -0.033        | -0.023       | 0.246         | 0.036         | -0.007        | 0.650**  |
|        | Palampur | P     | -0.025        | 0.004         | -0.057        | 0.025         | <b>0.145</b> | 0.428         | 0.005        | 0.215         | 0.030         | 0.018         | 0.787**  |
|        |          | G     | 0.345         | -0.024        | 1.046         | -0.202        | <b>0.994</b> | -4.815        | 2.057        | 1.600         | -0.051        | -0.039        | 0.912**  |
|        | Pooled   | P     | -0.007        | -0.007        | -0.012        | 0.100         | <b>0.671</b> | -0.111        | -0.001       | 0.171         | -0.005        | -0.013        | 0.784**  |
|        |          | G     | -0.026        | 0.015         | 0.100         | 0.233         | <b>0.850</b> | -0.045        | 0.029        | -0.028        | -0.290        | -0.017        | 0.821**  |
| HI     | Berthin  | P     | 0.000         | -0.030        | 0.046         | 0.080         | -0.297       | <b>0.269</b>  | 0.009        | -0.004        | -0.006        | 0.002         | 0.067    |
|        |          | G     | 0.049         | 0.015         | 0.047         | 0.077         | -0.169       | <b>0.063</b>  | 0.007        | -0.045        | 0.025         | -0.004        | 0.066    |
|        | Palampur | P     | 0.023         | -0.005        | 0.045         | 0.005         | -0.124       | <b>-0.500</b> | -0.010       | -0.202        | -0.028        | 0.014         | -0.780** |
|        |          | G     | -0.285        | 0.070         | -0.596        | -0.247        | -0.809       | <b>5.911</b>  | -3.351       | -1.527        | 0.043         | -0.056        | -0.848** |
|        | Pooled   | P     | 0.017         | -0.006        | 0.018         | 0.039         | -0.336       | <b>0.222</b>  | -0.008       | -0.052        | 0.003         | -0.003        | -0.106   |
|        |          | G     | 0.058         | 0.023         | -0.140        | 0.098         | -0.429       | <b>0.088</b>  | -0.051       | 0.012         | 0.204         | -0.004        | -0.142   |
| SPP    | Berthin  | P     | 0.000         | -0.035        | 0.001         | 0.031         | -0.057       | 0.012         | <b>0.186</b> | -0.007        | -0.009        | -0.002        | 0.120    |
|        |          | G     | 0.024         | 0.002         | 0.022         | 0.036         | -0.061       | 0.004         | <b>0.124</b> | -0.014        | 0.042         | -0.004        | 0.175    |
|        | Palampur | P     | 0.039         | 0.001         | 0.016         | -0.019        | 0.022        | 0.166         | <b>0.031</b> | 0.066         | 0.032         | -0.011        | 0.342*   |
|        |          | G     | -0.611        | 0.031         | 0.130         | 0.354         | 0.503        | -4.878        | <b>4.062</b> | 0.969         | 0.006         | 0.061         | 0.627**  |
|        | Pooled   | P     | -0.006        | 0.013         | 0.004         | 0.001         | -0.004       | -0.009        | <b>0.192</b> | -0.038        | -0.007        | -0.005        | 0.142    |
|        |          | G     | -0.043        | -0.035        | -0.097        | 0.018         | 0.055        | -0.010        | <b>0.441</b> | 0.005         | -0.063        | -0.017        | 0.255    |
| PP     | Berthin  | P     | 0.000         | 0.039         | 0.002         | 0.161         | 0.300        | -0.017        | -0.022       | <b>0.064</b>  | -0.012        | 0.005         | 0.520**  |
|        |          | G     | -0.034        | -0.027        | -0.005        | 0.203         | 0.242        | -0.009        | -0.005       | <b>0.334</b>  | 0.002         | -0.017        | 0.684**  |
|        | Palampur | P     | 0.036         | -0.001        | -0.051        | 0.009         | 0.114        | 0.370         | 0.007        | <b>0.273</b>  | 0.045         | 0.011         | 0.814**  |
|        |          | G     | -0.537        | 0.144         | 0.932         | 0.403         | 0.866        | -4.915        | 2.143        | <b>1.837</b>  | -0.036        | 0.022         | 0.857**  |
|        | Pooled   | P     | -0.006        | -0.002        | -0.006        | 0.064         | 0.383        | -0.039        | -0.024       | <b>0.300</b>  | -0.006        | -0.011        | 0.652**  |
|        |          | G     | -0.031        | 0.001         | 0.055         | 0.200         | 0.649        | -0.029        | -0.059       | <b>-0.036</b> | 0.043         | -0.011        | 0.782**  |
| PL     | Berthin  | P     | 0.000         | -0.016        | -0.003        | 0.104         | 0.095        | 0.036         | 0.036        | 0.016         | <b>-0.047</b> | 0.003         | 0.223    |
|        |          | G     | -0.055        | -0.021        | 0.008         | 0.190         | 0.096        | 0.013         | 0.042        | 0.004         | <b>0.123</b>  | -0.011        | 0.389**  |
|        | Palampur | P     | 0.029         | -0.001        | -0.047        | 0.026         | 0.033        | 0.103         | 0.007        | 0.092         | <b>0.134</b>  | 0.013         | 0.390**  |
|        |          | G     | -0.382        | 0.131         | 1.494         | 0.013         | 0.269        | -1.364        | -0.122       | 0.357         | <b>-0.187</b> | -0.028        | 0.181    |
|        | Pooled   | P     | 0.002         | -0.011        | -0.004        | 0.082         | 0.177        | -0.029        | 0.060        | 0.091         | <b>-0.021</b> | 0.000         | 0.347*   |
|        |          | G     | 0.007         | 0.090         | 0.096         | 0.399         | 0.439        | -0.032        | 0.050        | 0.003         | <b>-0.561</b> | 0.014         | 0.505**  |
| HSW    | Berthin  | P     | 0.000         | -0.029        | 0.020         | -0.054        | 0.069        | 0.014         | -0.014       | 0.011         | -0.004        | <b>0.030</b>  | 0.044    |
|        |          | G     | -0.043        | 0.016         | 0.017         | -0.055        | 0.040        | 0.004         | 0.008        | 0.100         | 0.024         | <b>-0.056</b> | 0.057    |
|        | Palampur | P     | 0.048         | -0.010        | -0.025        | -0.004        | 0.013        | -0.036        | -0.002       | 0.015         | 0.009         | <b>0.198</b>  | 0.205    |
|        |          | G     | -0.453        | 0.252         | 0.644         | 0.125         | 0.083        | 0.710         | -0.522       | -0.084        | -0.011        | <b>-0.471</b> | 0.271    |
|        | Pooled   | P     | -0.004        | 0.017         | 0.003         | -0.033        | 0.130        | 0.009         | 0.015        | 0.046         | 0.000         | <b>-0.070</b> | 0.113    |
|        |          | G     | -0.016        | -0.059        | 0.048         | -0.095        | 0.156        | 0.004         | 0.079        | -0.004        | 0.084         | <b>-0.093</b> | 0.104    |

**Abbreviations :** DFFL= Days to 50 % flowering; DSFM= Days to 75% maturity; PH= Plant height; BPP= Branches / plant; BYP= Biological yield / plant; HI= Harvest index; SPP= Seeds / pod; PP= Pods / plant; PL= Pod length; HSW= 100-seed weight; YPP= Yield / plant

**Residual effects at Phenotypic level (P) = 0.185, 0.776 and 0.149      Residual effects at Genotypic level (G) = 0.185, 0.147 and 0.153**

\*\* and \* Significant at 1% and 5% level

index showed a significant negative association with grain yield chiefly due to its direct as well as indirectly through pods/plant, biological/plant, seeds/pod, and pod length, likewise the genotypic path was also negative indirectly through seeds/pod, pods/plant, biological/plant, plant height, days to 50% flowering and branches/plant. The positive and significant correlation of seeds/pod exhibited due to its direct and indirectly *via* harvest index, pods/plant, biological yield/plant, days to 50% flowering, plant height, and pod length at the phenotypic level, on the other hand, at the genotypic level it was chiefly due to its direct and indirectly through pods/plant, biological yield/plant, branches/plant and plant height. Similarly, a significant positive association of pods/plant with grain yield was reported at the phenotypic level mainly due to its direct effect and indirectly through biological yield/plant, harvest index, pod length, days to 50% flowering, and genotypic path reported mainly due to its direct effect and indirectly *via* seeds/pod, plant height, biological yield/plant and branches/plant. The phenotypic path of pod length pertained to positive correlation primarily due to its direct effect as well as indirectly through harvest index, pods/plant, biological yield/plant, days to 50% flowering, and branches/plant. Pods/plant with grain yield was reported mainly due to its direct effect and indirectly *via* seeds/pod, plant height, biological yield/plant and branches/plant at the genotypic level only.

The residual effects at Berthin ( $p=0.185$ ,  $g=185$ ), Palampur ( $p=0.147$ ,  $g=0.776$ ), and pooled ( $p=0.153$ ,  $g=0.149$ ) suggesting that most of the variability was covered by the traits under study. The parallelism between our results for path coefficient was found by Punia *et al.* (2014) for the number of pods/plant and the number of branches/plant. Kumar *et al.* (2015) for cluster/plant and harvest index on grain yield. Patidar and Sharma (2017) reported the highest direct effect of the number of branches/plant, number of pods/plant, biological yield/plant, and plant height with seed yield. Goswami *et al.* (2020) for biological yield/plant had a significant direct effect on urdbean yield. Khan *et al.* (2020) reported the highest positive direct effect of cluster/plant and harvest index on grain yield, suggesting the selection of these traits would be advantageous.

## CONCLUSION

Our findings from 23 urdbean genotypes cultivated in two different locations in the Northwestern Himalayan region revealed the

significant variability among the genotypes and can be used as parents in further genetic amelioration. The genotypes Sirmour-1, Kangra-1, and Chamba-6 were observed to be the best genotypes based on mean performance, thus can be directly used as a variety by re-evaluating in yield trials or can be included in blackgram breeding programs as parent(s). The magnitude of PCV is higher than the GCV with the minor difference indicating the tight association among the traits. The heritability coupled with genetic advance as percent of mean was maximum in harvest index followed by yield per plant, referring to favorable selection for the traits. Taking into account the nature and magnitude of the inter-relation of the traits and their direct and indirect effects, it can be concluded that grain yield/plant was significantly and positively associated with branches/plant, biological yield/plant, pods/plant, and pod length. Thus, addressing these traits in the selection process would be advantageous to enhance grain yield. As per path coefficient analysis, the direct positive effects of the three characteristics biological yield/plant, branches/plant and pods/plant were associated with positive correlations with grain yield/plant. Therefore, selection for these characteristics might culminate in an increase in yield along with yield-related traits.

## CONFLICT OF INTEREST

All the authors declared no conflict of interest.

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