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# Estimation of genetic variability and implications of direct and indirect effects of different traits on leaf yield in bathua (C*henopodium album*)*

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*Chenopodium* is a genus of about 250 species of flowering plants (Giusti 1970) and contains several plants of minor to moderate importance as food crops, both leafy vegetables and pseudo cereals. Four species, namely *Chenopodium album*, *C.quinoa*, *C. nutaliae* and *C. pallidicaule*, are known to be cultivated in genus *Chenopodium*. Out of the four domesticated species, *C. album* (bathua) is the most widely distributed fast growing annual plant grown in the Himalayan region (Partap *et al*., 1998). In some parts of north India, chenopodium leaves, also known as bathua, are used for culinary purposes. The leaves and young shoots are eaten as leafy vegetable either steamed in its entirety or cooked like spinach. Bathua is an under utilized vegetable whose potential value is under estimated and under exploited. It is nutritionally superior (Partap *et al*. 1998) to most major leafy vegetables and adapted to low-input agriculture so it is important for local communities. Genetic variability is the key in success of developing new varieties. Therefore, an attempt was made to study different components of genetic variability and inter-relationship among important traits in bathua.

Sixty germplasm of bathua (*C. album*) comprising seven exotic (EC) and 42 indigenous collections (IC) obtained from NBPGR, RS, Shimla, and 10 local collections made from Kullu valley along with a standard check variety Pusa Bathua 1 were evaluated during rainy (*kharif*) season of 2006 and 2007 at the IARI, Regional Station, Katrain, Kullu. The experiment was laid out in a randomized complete block design with 2 replications maintaining row-to-row distance at 45 cm and plant-to-plant spacing at 15 cm. Data on leaf yield and contributing characters, viz, plant height, leaf length, leaf width and number of leaves/plant were recorded on five randomly selected plants in each replication. Pooled data for the two years were analyzed statistically. The analysis of variance was done as per Sukhatme and Amble (1995). Different components of genetic variability, correlation coefficients and path coefficients were computed following SPAR 1 computer package developed by the IASRI, New Delhi (Doshi and Gupta 1991).

*Per se* performance of the 60 genotypes of bathua is given in Table 1. Significantly higher leaf yield/plant than the check variety Pusa Bathua I was obtained in genotypes IC 108086 (392.1 g), IC 415494 (381.3 g), EC 507733 (344.8 g) and IC 444180 (266.0 g). More number of leaves over the check variety was recorded in NIC 22532 (553.1), NIC 22530 (389.8), NIC 22501 (374.8), EC 507733 (360.0), IC 415494 (346.0) and IC 108086 (328.1).

*Variability analysis*

The analysis of variance revealed the significance of mean squares due to varieties for all the five characters. The extent of variability with respect to the five polygenic characters in 60 genotypes measured in terms of range, genotypic, phenotypic and environmental variances, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability estimates in broad sense ($H^2$), expected genetic advance and the expected genetic advance as per cent of mean are presented in Table 2. A considerable amount of variation was observed for all the characters as also reported by Bhargava *et al*. (2003a, b). Plant height ranged from 38 to 140 cm. A very wide range from 27.6 to 555.3 was observed for number of leaves/ plant. Leaf length and leaf width ranged from 3.0 to15.5 cm and 1.6 to16.0 cm, respectively. Leaf yield ranged from 12.4–435.3 g/plant. The genotypic variance was maximum for number of leaves/plant (4816.9), followed by leaf yield/plant (2421.5). The PCV was higher than GCV in all the characters, indicating the role of environment in expression of genotypes. The GCV estimates were maximum for number of leaves/plant (46.75%), followed by leaf width (47.07%) and leaf yield/

* Short note

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Table 1 Mean performance of 60 genotypes of bathua for five quantitative traits

| Genotype | Plant height (cm) | No. of leaves | Leaf length (cm) | Leaf width (cm) | Leaf yield/ plant (g) |
|---|---|---|---|---|---|
| NIC 15022 | 106.6 | 207.3 | 13 | 12 | 231.6 |
| NIC 22490 | 63.1 | 67.3 | 8 | 2.1 | 38.6 |
| NIC 22501 | 116.0 | 374.8 | 8.2 | 2.6 | 46.4 |
| NIC 22491 | 78.1 | 164.0 | 14 | 8.6 | 101.6 |
| NIC 22494 | 79.4 | 71.9 | 12.5 | 11.4 | 40.2 |
| NIC 22497 | 96.1 | 99.3 | 14 | 14.2 | 55.2 |
| NIC 22498 | 90.3 | 76.9 | 11.7 | 3.7 | 30.1 |
| NIC 22492 | 113.9 | 135.9 | 12.8 | 8.6 | 107.4 |
| NIC 22495 | 98.1 | 95.8 | 11.8 | 10.2 | 61.0 |
| NIC 22503 | 111.1 | 88.4 | 12.2 | 8.2 | 32.6 |
| NIC 22504 | 99.9 | 112.0 | 10.7 | 7.1 | 70.9 |
| NIC 22505 | 92.3 | 108.4 | 12.2 | 10.2 | 56.5 |
| NIC 22506 | 104.1 | 117.5 | 12.5 | 7.2 | 85.8 |
| NIC 22507 | 109.0 | 126.8 | 12.5 | 12 | 118.1 |
| NIC 22508 | 123.1 | 188.5 | 13 | 11 | 101.6 |
| NIC 22510 | 105.4 | 121.3 | 11 | 6.5 | 54.8 |
| NIC 22511 | 90.3 | 132.6 | 11 | 9.15 | 78.8 |
| NIC 22514 | 103.6 | 160.8 | 8 | 5 | 79.8 |
| NIC 22515 | 95.6 | 70.3 | 13 | 12.7 | 40.2 |
| NIC 22517 | 105.0 | 86.3 | 10.5 | 8.2 | 48.1 |
| NIC 22518 | 87.4 | 208.3 | 6.5 | 4 | 173.6 |
| NIC 22520 | 95.4 | 78.1 | 12.2 | 10 | 37.2 |
| NIC 22525 | 85.4 | 140.8 | 12.7 | 13 | 99.5 |
| NIC 22530 | 97.6 | 389.8 | 6 | 1.7 | 53.4 |
| NIC 22531 | 91.6 | 74.3 | 10.2 | 9.3 | 34.8 |
| NIC 22532 | 98.5 | 553.1 | 5.5 | 3.7 | 68.5 |
| NIC 22533 | 91.8 | 86.3 | 11.5 | 10 | 43.2 |
| EC 507733 | 112.3 | 360.0 | 10.6 | 4 | 344.8 |
| EC 507737 | 93.5 | 153.8 | 8.7 | 6 | 119.3 |
| EC 507741 | 97.6 | 209.5 | 7 | 5 | 169.3 |
| EC 507742 | 84.1 | 197.3 | 5.7 | 3.2 | 152.3 |
| EC 507744 | 92.1 | 110.8 | 3.2 | 2 | 49.5 |
| EC 507746 | 67.8 | 108.8 | 4.2 | 2.7 | 42.2 |
| EC 557748 | 40.8 | 66.8 | 3.6 | 2.3 | 60.5 |
| IC 107515 | 113.3 | 102.9 | 11.7 | 7 | 99.3 |
| IC 108086 | 102.6 | 328.1 | 5.7 | 1.7 | 392.1 |
| IC 201680 | 102.6 | 140.8 | 15.2 | 15.2 | 188.2 |
| IC 341707 | 80.6 | 145.8 | 11.7 | 10.7 | 137.3 |
| IC 341710 | 97.8 | 102.9 | 12.7 | 12.5 | 84.9 |
| IC 363733 | 73.1 | 80.3 | 7.7 | 6.7 | 37.8 |
| IC 381106 | 103.6 | 94.1 | 8.4 | 2 | 40.8 |
| IC 382223 | 128.3 | 155.1 | 9.2 | 3.7 | 39.5 |
| IC 415493 | 46.8 | 264.4 | 3 | 1.5 | 199.5 |
| IC 415494 | 106.5 | 346.0 | 13.2 | 11 | 381.3 |
| IC 444179 | 119.9 | 137.8 | 13.7 | 7.2 | 222.7 |
| IC 444180 | 110.0 | 194.3 | 12 | 8.2 | 266.0 |
| IC 469275 | 94.3 | 165.9 | 11 | 9.7 | 167.2 |
| IC 469276 | 62.0 | 112.6 | 10.5 | 12.2 | 135.1 |
| IC 469277 | 111.0 | 153.8 | 13.2 | 10.5 | 195.9 |
| Ooty | 67.7 | 42.5 | 5.5 | 6.5 | 17.2 |
| Lag Valley | 71.0 | 58.2 | 11 | 8.2 | 28.9 |
| Malana I | 57.5 | 41.0 | 12.5 | 10 | 18.5 |
| Malana II | 113.8 | 99.1 | 12.5 | 10 | 130.3 |
| Sangchar | 97.8 | 124.5 | 11.5 | 9.5 | 175.0 |
| Pangan | 91.9 | 74.4 | 12 | 9 | 55.6 |
| Kothi Maharaja | 89.9 | 86.6 | 10.2 | 6.2 | 51.0 |
| Halan I | 71.8 | 65.9 | 8.2 | 6 | 22.7 |
| Halan II | 45.9 | 27.8 | 13.5 | 8.5 | 43.9 |
| Local I | 100.0 | 143.6 | 13 | 8.5 | 52.1 |
| Pusa Bathua-I (check) | 103.5 | 286.3 | 10.2 | 4.2 | 217.6 |
| CD ($P$=0.05) | 17.33 | 25.24 | 1.81 | 1.62 | 43.47 |

plant (46.43%). Heritability (broad sense) estimates were high (>80%) for all the five characters. Bhargava *et al.* (2006) have also reported high heritability estimates for plant height and leaf size in *C. quinoa*. The estimates of genetic advance expressed as per cent of mean were observed maximum for number of leaves/plant (95.01%), followed by leaf width (93.46%) and leaf yield (88.65%).

In spite of high heritability values for all the characters, estimates of expected genetic advance as per cent of mean ranged from 35.86% to 95.01%. High heritability (>80%) accompanied with high genetic advance as per cent of mean (>80%) observed for number of leaves per plant , leaf width and leaf yield/plant will be more useful than heritability alone and considerable improvement could be made in these characters by predicting the results and selecting the best individual. High heritability along with high genetic gain indicated in these characters was due to considerable additive gene effects. Plant height and leaf length had high heritability but low genetic gain, such characters are more likely to be under the control of non-additive gene action and selection for these characters will be less effective.

The inadequate knowledge of interrelationship among various traits and the practice of unilateral selection for agronomic traits frequently end up in retrograde or less than optimum results in plant breeding. A correlation between different characters is an aspect which should be kept in mind for better planning of selection programmes.

The genotypic correlation coefficients were in general higher in magnitude than the corresponding phenotypic correlation coefficients (Table 3). Number of leaves per plant and plant height showed significant and positive correlation with leaf yield/plant (0.5461 and 0.2879 respectively). Plant height also showed positive and significant association with number of leaves/plant, leaf length

Table 2 Estimates of mean, range, variance components and genetic parameters for various quantitative traits in bathua

| Character | Mean ± SE | Range | $\sigma^2g$ | $\sigma^2p$ | $\sigma^2e$ | GCV (%) | PCV (%) | $H^2$ | GA | GA as % of mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | 93.0 ± 6.1 | 38-140 | 324.8 | 399.8 | 75.0 | 19.37 | 21.49 | 0.81 | 33.35 | 35.86 |
| No. of leaves/plant | 148.4 ± 8.9 | 27.6-555.3 | 4816.9 | 4976.0 | 159.1 | 46.75 | 47.53 | 0.97 | 141.0 | 95.01 |
| Leaf length (cm) | 10.3 ± 0.64 | 3.0-15.5 | 8.79 | 9.61 | 0.82 | 28.73 | 30.09 | 0.91 | 5.81 | 56.42 |
| Leaf width (cm) | 7.5 ± 0.57 | 1.5-16.0 | 12.48 | 13.14 | 0.66 | 47.07 | 48.26 | 0.94 | 7.01 | 93.46 |
| Leaf yield/plant (g) | 105.5 ± 15.36 | 12.4-435.3 | 2421.5 | 2853.5 | 472.0 | 46.43 | 50.98 | 0.85 | 93.5 | 88.65 |

ó²g, Genotypic variance; ó²p, phenotypic variance; ó²e, environmental variance; GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; GA, genetic advance; $H^2$, heritability coefficient (broad sense)

Table 3 Genotypic, phenotypic and environmental correlation coefficients for five characters in bathua

| Character | | No. of leaves | Leaf length | Leaf width | Leaf yield/ plant |
|---|---|---|---|---|---|
| Plant height | G | 0.3319* | 0.3814* | 0.1242* | 0.2879* |
| | P | 0.3194 | 0.3605 | 0.1450 | 0.2870 |
| | E | 0.4155 | 0.2514 | 0.3705 | 0.3344 |
| No. of leaves | G | | –0.3002* | –0.3618* | 0.5461* |
| | P | | –0.2802 | –0.3470 | 0.5419 |
| | E | | 0.1237 | 0.0933 | 0.5385 |
| Leaf length | G | | | 0.8266* | 0.0560 |
| | P | | | 0.8027 | 0.0606 |
| | E | | | 0.4939 | 0.1215 |
| Leaf width | G | | | | 0.0015 |
| | P | | | | 0.0006 |
| | E | | | | -0.0138 |

*Significant at $P$=0.05

and leaf width. But number of leaves/plant showed significant and negative correlation with leaf length and leaf width. Leaf length had significant positive association with leaf width.

Correlations of agronomic and morphological characters with yield in different crops have been reported by several workers. Although these estimates are helpful in determining the components of a complex trait, such as yield, they do not provide an exact picture of the relative importance of direct and indirect influences of each of the component characters towards this trait. Path coefficient analysis is a standardized partial regression analysis appears to be helpful in partitioning the correlation coefficients into direct and indirect effects. Path coefficient analysis reveals the true nature of cause and effect relationships and wherever feasible path coefficient analysis should be conducted in addition to simple correlation analysis.

Path coefficient analysis (Table 4) revealed that at genotypic level number of leaves/plant had highest direct effect (0.6279) on leaf yield/plant, followed by leaf length (0.1728) and leaf width (0.0854). Plant height had the least direct effect (0.0030) on leaf yield. Direct selection for number of leaves/plant would be beneficial for bringing improvement as it has also shown significant positive correlation with leaf

Table 4 Path coefficient analysis showing direct (in bold) and indirect effects of four traits over leaf yield in bathua

| Character | Plant height | No. of leaves | Leaf length | Leaf width | Correlation with leaf yield/plant |
|---|---|---|---|---|---|
| Plant height | **0.0030** | 0.2084 | 0.0659 | 0.0106 | 0.2879 |
| No. of leaves | 0.0010 | **0.6279** | –0.0519 | –0.0309 | 0.5461 |
| Leaf length | 0.0012 | –0.1885 | **0.1728** | 0.0706 | 0.0560 |
| Leaf width | 0.0004 | –0.2272 | 0.1428 | **0.0854** | 0.0015 |

yield (0.5461). Plant height has shown maximum positive indirect effect (0.2084) via number of leaves towards leaf yield. Leaf length and leaf width have shown negative indirect effects via number of leaves while positive indirect effects for the remaining characters were observed.

It may be concluded that for increasing leaf yield in bathua, direct selection for higher number of leaves may be practised. Genotypes IC 108086, IC 415494 and EC 507733 possessed the desired attributes and may directly be used in breeding programmes for obtaining higher leaf yields.

## SUMMARY

The present investigations were undertaken to study variability and analyze the inter-relationship among five quantitative characters in 60 indigenous and exotic germplasm lines of bathua (*Chenopodium album)*. All the traits revealed a considerable amount of variation among the germplasm lines. The extent of variation ranged from 12.4–435.3 g/plant for leaf yield. The phenotypic coefficients of variation were higher than genotypic coefficients of variation for all the characters. The estimates of genotypic coefficient of variation were higher for number of leaves/plant (46.75%), followed by leaf width (47.07%) and leaf yield/plant (46.43%). Heritability estimates ($H^2$) were high (>80%) for all the five characters. In spite of high heritability values for all the traits, the expected genetic advance as per cent of mean ranged from 35.86 to 95.01. The genotypic correlation coefficients were in general higher in magnitude than the corresponding phenotypic correlation coefficients. All the characters were positively correlated with leaf yield but significant and positive correlation with leaf yield were shown

only by plant height and number of leaves/plant. Path coefficient analysis revealed that number of leaves had highest direct effect (0.6279) on leaf yield, followed by leaf length (0.1728) and direct selection could be made for these characters for improving leaf yield. Plant height showed maximum positive indirect effect (0.2084) via number of leaves towards leaf yield hence simultaneous selection for number of leaves/plant and plant height can be made for the improvement of leaf yield in bathua.

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