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# GENETIC ANALYSIS OF *RABI* ONION (*ALLIUM CEPA* L.) GENOTYPES: VARIABILITY, HERITABILITY, AND GENETIC ADVANCE IN THE NEW GANGETIC ALLUVIAL PLAINS OF WEST BENGAL INDIA

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**ABSTRACT**

Onion (*Allium cepa* L.) is an economically significant vegetable crop exhibiting extensive genetic variability. This study evaluates eighteen open-pollinated onion genotypes to assess genetic variability, heritability, and genetic advance for yield and quality traits. The experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, using a randomized block design (RBD) with three replications. Observations were recorded on key agronomic and biochemical traits, including plant height, neck thickness, bulb weight, total yield, thrips incidence, Stemphylium blight severity, total soluble solids (TSS), and pyruvic acid content.

Analysis of variance revealed significant differences among genotypes, indicating substantial genetic diversity. High phenotypic (PCV) and genotypic (GCV) coefficients of variation were observed for traits such as neck diameter, bulb weight, reducing sugars, pyruvic acid, and yield parameters, suggesting their potential for selection. Heritability estimates ranged from 22% to 100%, with traits like total yield, marketable yield, TSS, and pyruvic acid content exhibiting high heritability coupled with high genetic advance, confirming strong additive genetic effects. DOGR-1626, NHRDF Red-2, and PRO-7 emerged as superior genotypes, demonstrating high yield potential and resilience to biotic stresses. The findings highlight the importance of genetic selection for improving onion yield and quality. The identified genotypes hold promise for breeding programs aimed at enhancing productivity and stress tolerance in the new alluvial region of West Bengal.

***Key words*: Onion, Genotypes, Variability, Heritability, Genetic advance, Selection, Breeding**

## Introduction

Onion (*Allium cepa*) is one of the most widely cultivated vegetables globally, ranking second after potato in terms of production. It belongs to the bulb family Alliaceae (previously classified under Liliaceae and Amaryllidaceae) and is characterized by superior ovaries and umbellate inflorescences. According to Vavilov (1951), the onion is believed to have originated in Central Asia and the Middle East, which is considered its secondary center of origin.

Onions are an essential vegetable in kitchens worldwide, occupying a prominent place in daily cooking. In India, onions are grown across 1.91 million hectares, with an annual production of approximately 31.12 million tonnes (FAOSTAT, 2023). Globally, India ranks second in both area and production, following China, and holds a 24.8% share of the world market. Maharashtra is the largest producer of onions in India, contributing 42.53% of the country's total production, followed by Madhya Pradesh (15.16%), Karnataka (14%), and Gujarat (9%) (NHB, 2020).

Onion exhibits extensive morphological diversity across traits such as plant height, leaf structure, bulb characteristics (size, color, shape), flower color, fertility, and bulbils development, as noted by Pooler and Simon (1993). Prior to initiating breeding programs, it is critical to evaluate the genetic variation present in indigenous genotypes for yield-related traits. Parameters such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) serve as key metrics for quantifying variability within germplasm collections. Heritability estimates reveal the environmental influence on trait expression and the potential for genetic gain through selective breeding. Therefore, characterizing genotypes is essential for assessing genetic diversity and identifying promising genotypes to drive future breeding initiatives.

## Methodology

The current research investigation employed eighteen onion genotypes namely JRO-14-14, NHO-920, PRO-9, L-913, Kasi No.1, Balwan, Rashidpura, Sandeep, Sona, DOGR-1639, PRO-8, DOGR-1625, DOGR-1626, Bhima Shakti, Bhima Kiran, NHRDF Red -2, Phule Samarth and PRO-7 are collected from DOGR, Rajgurunagar, Maharashtra, India as part of the All India Network Programme Onion and Garlic project during *Rabi* 2021. Bidhan Chandra Krishi Viswavidyalaya is the network program's primary short-day center. The experiment was conducted in "C" Block Farm, Bidhan Chandra Krishi Viswavidyalaya in Kalyani, West Bengal.

The experiment was carried out in a randomized block design (RBD) with three replications at the "C" Block Farm of Bidhan Chandra Krishi Viswavidyalaya. Thirty-five-day-old onion seedlings were transplanted with a spacing of 15 cm between rows and 10 cm between plants. For each genotype, ten representative plants were randomly selected per replication to record observations on the following traits: plant height (cm), number of leaves per plant, neck thickness (mm), polar diameter (mm), equatorial diameter (mm), average bulb weight (g), days to harvest, thrips incidence (%), stemphylium blight incidence (%), total soluble solids (TSS, °Brix), reducing sugar (%), total sugar (%), pyruvic acid (µmol/g), dry matter (%), marketable yield (q $ha^{-1}$), and total yield (q $ha^{-1}$).

A total of eighteen open-pollinated onion genotypes were tested to assess the degree of variability for yield and its contributing traits. The presence of highly significant genotype variation across all traits indicates substantial diversity among the genotypes. Variability was observed for bulb yield and other quality characteristics, including plant height, number of leaves, bulb diameter (polar and equatorial), neck thickness, marketable bulb weight, thrips infestation, stemphylium blight, and sugar content (reducing and total sugars). The study also highlighted variability in total soluble solids, pyruvic acid content and yield parameters.

The statistical analysis included the calculation of phenotypic and genotypic coefficients of variation (PCV and GCV), heritability, genetic advance, and genetic advance as a percentage of the mean (GAM). These analyses were performed using SPSS software. The findings indicated broad variability in the characteristics of the genotypes, confirming the potential for selection and improvement, particularly for traits influencing yield.

## Results and Discussion

The data obtained from these experiments were subjected to statistical analyses to extract meaningful insights. The analysis of variance indicated significant differences among genotypes for all traits, highlighting the presence of genetic variability and potential for improvement. Similar findings on genetic variability for bulb yield in onion have been reported by Mohanty and Prusti (2001); Pavlovic *et al.,* (2003); Hosamani *et al.,* (2010) & Ibrahim *et al.,* (2013).

Among the eighteen onion genotypes evaluated, DOGR-1626 exhibited the greatest plant height and highest number of leaves per plant, followed by NHRDF Red-2, whereas Balwan recorded the shortest plant height (Table 2). The genotype Rashidpura demonstrated the most desirable minimum neck thickness, with Kasi No.01 ranking next. Key yield-related traits, including average

**Table 1:** Analysis of variance.

| Source | df | Mean sum of Square | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PH (cm) | NOL | ND (mm) | PD (mm) | ED (mm) | AWB (g) | DTH (days) | TI (%) | SBI (%) | TSS (°B) | RS | TS | PA | MY (q/ha) | TY (q/ha) |
| Replication | 2 | 5.58 | 0.24 | 6.14 | 23.86 | 6.55 | 38.14 | 741.13 | 330.29 | 43.50 | 0.09 | 0.01 | 0.17 | 0.01 | 5.08 | 2.93 |
| Genotypes | 17 | 141.59 ** | 1.84 ** | 4.69 NS | 37.87 ** | 20.15 ** | 248.25 ** | 84.49 * | 346.37 ** | 251.89 ** | 5.37 ** | 1.35 ** | 1.0 ** | 2.04 ** | 6274.11 ** | 6330.7 ** |
| Error | 34 | 20.98 | 0.34 | 2.55 | 5.51 | 7.25 | 85.44 | 22.95 | 102.29 | 46.56 | 0.15 | 0.02 | 0.33 | 0.05 | 5.24 | 6.35 |

*Significant at 5% level (3.59), ** Significant at 1% level (6.11), NS- Non-Significant

**Table 2:** Mean performance of open pollinated genotypes *Rabi* onion.

| Geno-type | PH (cm) | NOL | ND (mm) | PD (mm) | ED (mm) | AWB (g) | DTH | MY (q/ha) | TY (q/ha) | SB (PDI) | TI (%) | TSS (%) | RS (%) | TS (%) | PA (µmole/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JRO-14-14 | 62.63 | 7.5 | 3.93 | 42.73 | 44.47 | 51.17 | 120 | 136.49 | 137.13 | 39.59 | 30 | 11.5 | 2.81 | 2.9 | 1.82 |
| NHO-920 | 58.5 | 7.9 | 6.56 | 48.5 | 46.5 | 64.1 | 108 | 164.1 | 165.7 | 21.09 | 34.67 | 13.2 | 2.42 | 2.5 | 3.84 |
| PRO-9 | 66.4 | 8.63 | 3.92 | 42.6 | 48.77 | 69.47 | 120 | 217.42 | 217.88 | 17.76 | 27.33 | 10.2 | 3.25 | 3.35 | 3.89 |
| L-913 | 61.83 | 8.67 | 5.05 | 45.57 | 48.36 | 72.7 | 120 | 234.38 | 234.78 | 19.98 | 23.33 | 11.6 | 2.83 | 3.26 | 3.35 |
| Kasi No.01 | 62.87 | 8.1 | 3.65 | 44.23 | 43.87 | 49.03 | 117 | 146.47 | 147.2 | 20.7 | 41.33 | 10.6 | 2.17 | 2.29 | 4.23 |
| Balwan | 54.73 | 6.7 | 6.84 | 39.93 | 44.97 | 53.4 | 121 | 120.64 | 121.1 | 29.59 | 35.33 | 11.8 | 3.11 | 3.25 | 3.61 |
| Rashi dpura | 63.53 | 7.37 | 3.63 | 34.9 | 47.1 | 46.53 | 108 | 130.66 | 132.89 | 49.95 | 48 | 9 | 3.44 | 3.29 | 3.75 |
| Sandeep | 72.13 | 7.23 | 5.91 | 40.67 | 43.3 | 52.17 | 121 | 147.21 | 147.59 | 27.01 | 40.67 | 12.7 | 1.86 | 2.28 | 1.36 |
| Sona | 70.23 | 7.1 | 6.22 | 42.3 | 46.87 | 51.6 | 121 | 163.15 | 163.33 | 29.23 | 46.67 | 10.2 | 2.92 | 3.05 | 3.48 |
| DOGR-1639 | 59.17 | 7.43 | 7.97 | 37.87 | 43.13 | 48.47 | 117 | 167.05 | 167.62 | 38.48 | 46.67 | 9.7 | 2.51 | 2.6 | 2.03 |
| PRO-8 | 59.37 | 7.63 | 4.39 | 41.23 | 45.53 | 51.87 | 121 | 170.38 | 173.48 | 28.47 | 55.33 | 13.7 | 2.13 | 3 | 4.18 |
| DOGR-1625 | 56.67 | 6.97 | 5.42 | 43.67 | 48.37 | 55.23 | 124 | 183.9 | 184.74 | 24.79 | 18.67 | 10.1 | 3.1 | 3.67 | 3.71 |
| DOGR-1626 | 78.3 | 9.6 | 6.22 | 48.93 | 51.87 | 74.6 | 124 | 260.37 | 261.15 | 10.9 | 12 | 11.1 | 2.52 | 3.47 | 3.79 |
| Bhima Shakti | 72.87 | 8.73 | 4.98 | 46.53 | 49.13 | 63.3 | 123 | 247.16 | 248.25 | 17.39 | 12.67 | 11.7 | 4.04 | 4.45 | 3.85 |
| Bhima Kiran | 60.23 | 7.2 | 4.6 | 44.83 | 50.37 | 65.5 | 123 | 241.97 | 242.61 | 20.7 | 18 | 11.1 | 3.57 | 3.37 | 3.41 |
| NHRDF Red-2 | 75.43 | 8.9 | 4.26 | 47.2 | 50.97 | 70.8 | 123 | 251.23 | 255.27 | 21.83 | 16 | 12.8 | 3.25 | 3.36 | 3.51 |
| Phule Samarth | 56.83 | 8.1 | 4.33 | 41.93 | 47.2 | 60.4 | 117 | 153.39 | 154.06 | 28.47 | 17.33 | 10.2 | 3.7 | 4.01 | 3.38 |
| PRO-7 | 61.93 | 7.63 | 4.18 | 45 | 46.3 | 55.03 | 108 | 193.72 | 196.44 | 11.84 | 17.33 | 9.5 | 4.34 | 4.82 | 4.23 |

PH: Plant Height(cm); NOL: (Number of Leaves per plant); ND: (Neck Diameter in mm); PD: (Polar Diameter in cm); ED(cm); AWB: (Average weight of bulb in grams); DTH: (Days to Harvest); MY: (Marketable yield quintal per ha); TY: (Total yield quintal per ha); SBI: (Stemphylium blight incidence (PDI%); TI: (Thrips infestation in Damage Severity Percentage (Based on Rating Scale 1-5)); TSS: (Total soluble solids in Brix°); Reducing sugar (Percentage % w/w), Total sugar (Percentage % w/w); Pyruvic acid (µ mole/g of fresh weight)

bulb weight, polar diameter, equatorial diameter, marketable yield, and total yield, were maximized in DOGR-1626, followed by NHRDF Red-2. In terms of crop maturity, NHO-920, Rashidpura, and PRO-7 had the shortest days to harvest, while DOGR-1625 and DOGR-1626 exhibited the longest duration. Among the genotypes, PRO-8 experienced the highest incidence of thrips infestation, whereas DOGR-1626 showed the lowest susceptibility. Stemphylium blight severity was most pronounced in Rashidpura, while DOGR-1626 recorded the least severity, followed by PRO-7 and Bhima Shakti. The highest total soluble solids (TSS) content was observed in PRO-8, with NHO-920 and NHRDF Red-2 ranking next. Pyruvic acid content was greatest in PRO-7 and Kasi No.01. Similarly, PRO-7 exhibited the highest total sugar and reducing sugar content, followed by Bhima Shakti and Phule Samart.

### Variability, Heritability, and Genetic Advance

Significant genetic variability was observed for bulb yield and its contributing traits. Estimates of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, and genetic advance revealed a wide range of variability among genotypes. These findings align with previous studies by Mohanty and Prusti (2001), Pavlovic *et al*., (2003), Hosamani *et al*., (2010), and Ibrahim *et al*., (2013).

Phenotypic Coefficient of Variation (PCV) was notably elevated for traits such as neck diameter, average bulb weight, thrips infestation, Stemphylium blight

**Table 3:** Genetic Analysis of Growth Parameters in Open-Pollinated Onion (*Allium cepa* L.) Genotypes.

| | Mean | Range | | Variability | | $H^2$ | GA | GAM |
|---|---|---|---|---|---|---|---|---|
| | | Min | Max | GCV | PCV | | | |
| PH | 65.50±2.89 | 47.70 | 79.40 | 9.73 | 12.01 | 0.66 | 10.59 | 16.25 |
| NOL | 7.83±0.31 | 6.30 | 9.90 | 9.00 | 11.70 | 0.59 | 1.12 | 14.25 |
| ND | 4.97±0.78 | 2.21 | 10.90 | 16.50 | 35.35 | 0.22 | 0.81 | 15.86 |
| PD | 43.69±1.44 | 33.70 | 51.90 | 7.60 | 9.34 | 0.66 | 5.50 | 12.73 |
| ED | 46.89±1.62 | 38.50 | 54.20 | 4.40 | 7.23 | 0.37 | 2.59 | 5.51 |
| ABW | 58.37±5.09 | 40.90 | 94.80 | 12.56 | 20.16 | 0.39 | 9.46 | 16.13 |
| DTH | 119.15±0.11 | 99.98 | 133.46 | 3.80 | 7.26 | 0.27 | 4.87 | 4.10 |
| TI | 30.10±6.87 | 8.00 | 66.00 | 40.01 | 52.03 | 0.59 | 19.27 | 63.38 |
| SBI | 26.50±3.59 | 8.88 | 59.94 | 31.50 | 40.83 | 0.60 | 13.15 | 50.06 |
| TSS | 11.48±0.26 | 8.00 | 13.90 | 11.83 | 12.34 | 0.92 | 2.61 | 23.37 |
| RS | 2.90±0.09 | 1.76 | 4.56 | 22.23 | 22.81 | 0.95 | 1.34 | 44.62 |
| TS | 3.15±0.29 | 1.93 | 4.89 | 14.69 | 23.27 | 0.40 | 0.61 | 19.11 |
| PA | 3.12±0.04 | 1.33 | 4.29 | 24.16 | 24.24 | 0.99 | 1.69 | 49.59 |
| MY | 184.56±1.33 | 117.86 | 262.30 | 24.71 | 24.74 | 1.00 | 94.05 | 50.84 |
| TY | 185.70±1.42 | 118.90 | 264.30 | 24.66 | 24.66 | 1.00 | 94.44 | 50.73 |

GCV(Genotypic Coefficient of Variation); PCV(Phenotypic Coefficient of Variation); $H^2$ (Broad-Sense Heritability); GA(Genetic Advance); GAM(Genetic Advance as per Mean)

incidence, reducing sugar, total sugar, pyruvic acid content, marketable bulb yield, and total bulb yield. In contrast, plant height, number of leaves per plant, and total soluble solids exhibited moderately high PCV values. Similarly, Genotypic Coefficient of Variation (GCV) was significantly high for thrips infestation, Stemphylium blight incidence, reducing sugar, total sugar, pyruvic acid content, marketable bulb yield, and total bulb yield. Moderately high GCV values were observed for neck diameter, average bulb weight, total soluble solids, and total sugar. These findings underscore substantial genetic variability among the accessions, suggesting that these traits are highly responsive to selection and hold promise for targeted genetic improvement in breeding programs.

The phenotypic coefficient of variation (PCV) exceeded the genotypic coefficient of variation (GCV) for all traits studied, likely due to genotype-environment interactions or environmental influences modulating trait expression. Traits such as neck diameter, average bulb weight, thrips infestation, and Stemphylium blight incidence exhibited a wide disparity between PCV and GCV, indicating greater environmental sensitivity and susceptibility to fluctuations. Conversely, marketable yield, total yield, total soluble solids (TSS), reducing sugars, and pyruvic acid content showed a narrower PCV-GCV gap, suggesting stronger genetic control and relative stability under environmental variations. These findings align with earlier reports by Singh *et al.*, (2010) and Gurjar and Singhoria (2006), who highlighted similar patterns of environmental buffering in yield and biochemical traits.

Many horticultural and quality traits, including plant height, polar diameter, total yield, marketable yield, TSS, reducing sugar, and pyruvic acid content, exhibited high heritability (>60%). This suggests that a large proportion of phenotypic variance is attributed to genotypic variance, making selection based on phenotypic expression reliable. Johnson *et al.*, (1955) emphasized that heritability alone is insufficient for predicting selection response and that genetic advance along with heritability is a more useful measure.

The estimates of broad-sense heritability ranged from 22% (neck diameter) to 100% (marketable and total yielding parameters). High heritability values indicate a strong genetic influence on trait expression, suggesting that these traits are less affected by environmental factors. These results are in agreement with Pavlovic *et al.*, (2003) for bulb yield and Hosamani *et al.*, (2010) for plant height, polar diameter, marketable yield, total yield TSS, reducing sugar and pyruvic acid content in onion.

Broad-sense heritability ($H^2$) varied between 22.00% and 100.00% across the studied traits. The highest heritability estimates were observed for marketable bulb yield and total bulb yield (both 100.00%), followed by pyruvic acid content (99.00%), reducing sugar (95.00%), total soluble solids (TSS) (92.00%), plant height, and polar diameter (66.00%). In contrast, neck diameter (22.00%) and days to harvest (27.00%) exhibited significantly lower heritability.

Genetic advance as a percentage of the mean (GAM) was highest for thrips infestation (63.38%), followed by marketable yield (50.84%), total bulb yield (50.73%), Stemphylium blight incidence (50.06%), pyruvic acid content (49.59%), reducing sugar (44.62%), and TSS (23.37%). Traits such as neck diameter (4.10%) and equatorial diameter (5.51%) recorded minimal genetic advance.

Genetic advance measures the improvement achievable through selection. Heritability values in the broad sense are more meaningful when accompanied by genetic gain. The phenotypic coefficient of variation was consistently higher than the genotypic coefficient of variation for all traits. The high variability observed for total yield suggests ample scope for selecting high-yielding genotypes. Traits with moderate GCV and PCV values, along with high heritability and genetic advance, indicate additive gene action and minimal environmental influence, making them suitable for selection. However, yield is a complex trait influenced by multiple components and environmental interactions. Therefore, direct selection based solely on yield may not be effective in breeding programs.

Notably, traits including total yield, marketable yield, TSS, reducing sugar, and pyruvic acid content displayed both high heritability and high genetic advance, indicating strong additive genetic control and potential for effective selection. These results align with findings reported by Singh *et al*., (2010) and Mohanty (2002).

Traits such as plant height and polar diameter exhibited high heritability with moderate genetic advance as a percentage of the mean, indicating additive gene action. This suggests that direct selection would be effective in developing superior varieties. Traits such as thrips infestation and stemphylium blight incidence exhibiting moderate heritability coupled with high genetic advance as a percentage of mean (GAM) suggest that additive gene action predominantly controls their expression, making them highly responsive to selection (Burton and DeVane, 1953). Several studies on onion have reported similar trends, where traits such as bulb weight, marketable yield, and total yield displayed moderate heritability along with high GAM, indicating the presence of considerable genetic variability and the effectiveness of phenotypic selection in breeding programs (Golani *et al*., 2006; Mohanty and Prusti, 2001).

Traits exhibiting high heritability and high GAM, such as marketable yield, total yield, TSS, reducing sugar, and pyruvic acid content, can be effectively improved through direct selection. Traits with moderate heritability and high GAM, including thrips infestation and Stemphylium blight incidence, as well as those with high heritability but moderate GAM, such as plant height and polar diameter, can respond to selection but require careful environmental influence. Meanwhile, for traits with low heritability and low GAM, like days to harvest, breeding strategies should prioritize improving environmental conditions rather than relying solely on genetic selection.

A strategic breeding approach based on heritability and genetic advance enables the effective selection of onion genotypes for yield, quality, and stress tolerance. Direct selection is most effective for traits governed by additive effects, while non-additive traits require alternative breeding strategies such as hybridization or recurrent selection. For environmentally influenced traits, management practices and genotype-environment interactions should be considered to achieve desirable improvements.

## Conclusion

The study identified superior genotypes such as DOGR-1626, NHRDF Red-2, PRO-7, Bhima Shakti, NHO-920 and PRO-8 as promising genotypes for cultivation in the new alluvial region of West Bengal during the Rabi season. These genotypes exhibited high yield potential, better quality attributes, and resistance to major biotic stresses. The findings provide valuable insights for onion breeding programs aimed at improving yield and quality through selection of genetically superior genotypes.

## Authors' contributions

All authors contributed collaboratively to the study's conception, execution, and manuscript preparation, and all approved the final version for submission.

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