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GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE FOR YIELD AND QUALITY TRAITS IN ONION (ALLIUM CEPA L.) GENOTYPES DURING THE RABI SEASON

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ABSTRACT

The present investigation was conducted to assess genetic variability, heritability and genetic advance for morphological and biochemical traits in onion (*Allium cepa* L.) during the *Rabi* season of 2024-25 at the University of Horticultural Sciences, Bagalkot, Karnataka. Seventy onion genotypes and six standard checks were evaluated using an augmented block design. The results revealed considerable variability among the genotypes for the evaluated traits. Among morphological characters, G9 recorded the maximum plant height (74.21 cm), G63 the highest number of leaves (16.44), G12 the highest collar girth (22.00 mm), G5 the maximum polar diameter (82.05 mm) and G65 the highest equatorial diameter (89.25 mm) and bulb weight (232.50 g). For biochemical traits, G60 recorded the highest total soluble solids (27.30 °Brix) and FRAP antioxidant activity (1.25 mg AAE/g), G25 the highest dry matter content (39.05%), G58 the highest ascorbic acid content (15.36 mg/100 g fresh weight), G5 the highest total flavonoid content (3.86 mg QE/g fresh weight) and G67 the highest total phenolic content (93.97 mg GAE/g fresh weight). Number of leaves exhibited a GCV of 22.98%, heritability of 83.78% and GAM of 43.89%. Among biochemical traits, FRAP antioxidant activity recorded the highest GCV (60.87%) and GAM (115.29%), followed by dry matter content (55.99%), total phenolic content (53.55%) and total flavonoid content (46.34%). These findings indicate substantial genetic variability and promising selection potential for improving bulb characteristics, quality and antioxidant properties. The identified genotypes may serve as valuable material for further evaluation and onion breeding programmes.

KEYWORDS: Onion, genetic variability, heritability, genetic advance, bulb quality, biochemical traits, antioxidant activity

INTRODUCTION

Onion (Allium cepa L.) is an economically important bulb vegetable widely cultivated and consumed worldwide. It contributes to human nutrition through its supply of vitamin C, dietary fibre, minerals and bioactive phytochemicals, particularly flavonoids such as quercetin and organosulfur compounds. These compounds are associated with antioxidant activity and contribute to the characteristic pungency and flavour of onion (Griffiths et al., 2002; Slimestad et al., 2007). In India, onion is a major commercial horticultural crop and its productivity and bulb quality are important determinants of its market value. Therefore, the identification and utilization of genetic variability for yield and quality traits are essential for developing improved onion cultivars.

Genetic variability is the fundamental prerequisite for crop improvement, as the effectiveness of selection depends on the extent of heritable variation present within a population. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) are commonly used to assess the magnitude of variability in quantitative traits. The difference between these estimates provides an indication of the influence of environmental factors on phenotypic expression. Heritability estimates the proportion of phenotypic variation attributable to genetic differences, while genetic advance predicts the expected response to selection. Therefore, the joint assessment of heritability and genetic advance as a percentage of the mean provides a more reliable basis for identifying traits amenable to selection than heritability alone (Burton and De Vane, 1953; Johnson et al., 1955).

Previous studies have documented substantial genetic variability for growth, bulb yield and quality traits in onion. Mohanty and Prusti (2001) reported variability, heritability, correlation and path coefficients for traits in Kharif onion. Hosamani et al. (2010) also investigated genetic variability and character associations among onion genotypes. More recently, Hulagannavar et al. (2023) reported high heritability and genetic advance for important yield-related traits, including bulb weight and total bulb yield, indicating the potential for genetic improvement through selection. However, estimates of variability and selection parameters may differ with the genetic material evaluated and the environmental conditions under which the crop is grown.

In view of the importance of identifying superior onion genotypes, the present investigation was undertaken to estimate genetic variability, heritability and genetic advance for morphological, yield and quality traits in onion genotypes evaluated during the Rabi season. The findings are expected to facilitate the identification of promising genotypes and provide a basis for selecting desirable traits in onion improvement programmes.

MATERIALS AND METHODS

The field experiment was conducted during the Rabi season of 2024-25 at the University of Horticultural Sciences, Bagalkot, Karnataka, India. The experimental material comprised 70 onion (Allium cepa L.) genotypes collected from different regions of India, encompassing local cultivars, germplasm accessions, released varieties and hybrids. Six standard check varieties, Bhima Shweta, Bhima Shubhra, Bhima Safed, Bhima Red, Bhima Super, and Arka Kalyan, were included for comparison, for a total of 76 entries. We evaluated the genotypes under an augmented block design, replicated the standard checks, and assessed the test genotypes without replication. Recommended crop management practices were adopted uniformly to ensure optimum crop growth and development.

We recorded observations for morphological and bulb-related traits, including days to germination, plant height, number of leaves per plant, collar girth, polar diameter, equatorial diameter and bulb weight. Bulb quality was assessed using colour coordinates (L*, a* and b*), total soluble solids, dry matter, moisture content, number of rings, ascorbic acid, total flavonoid content, total phenolic content and antioxidant activity. The recorded data were statistically analysed using R software. Genotypic and phenotypic coefficients of variation, broad-sense heritability, genetic advance and genetic advance as a percentage of the mean were estimated to characterize the extent of variability and determine the scope for selection-based improvement of economically important traits in onion.

Table 1. Per se performance of onion genotypes for morphological and quality traits during rabi season

Genotype	DG	PH	NOL	CG	PD	ED	BW	L*	a*	b*	DM	M	TSS	NOR	ASC	TFC	FRAP	TPC
G1	5	66.27	12.10	19.74	62.87	67.88	101.25	33.94	7.02	5.30	21.16	78.84	13.75	9.5	11.52	2.67	0.63	36.11
G2	5	69.44	12.60	17.71	68.36	83.65	187.85	76.51	0.03	15.04	23.02	76.98	15.95	10.00	8.64	3.48	0.56	42.32
G3	5	68.03	11.70	20.45	65.05	77.51	171.00	42.57	2.67	10.83	18.43	81.57	21.4	9.00	6.72	1.95	0.13	45.26
G4	5	69.35	13.30	20.38	70.23	86.54	195.94	74.89	4.81	3.62	24.22	75.78	20.85	7.50	6.72	3.02	0.60	33.97
G5	5	71.92	10.80	21.16	82.05	80.99	204.28	42.50	3.01	11.10	21.25	78.75	15.15	10.00	8.64	3.86	0.33	61.89
G6	5	70.32	9.70	18.86	68.20	72.57	152.50	54.01	0.63	17.33	23.18	76.82	16.55	7.50	9.60	2.35	0.33	31.19
G7	5	66.06	10.40	18.37	65.09	76.20	175.86	81.51	0.70	13.62	15.64	84.36	14.5	8.50	8.64	3.21	0.58	82.74
G8	5	64.03	9.50	18.28	61.11	67.30	130.1875	58.29	3.09	11.43	14.98	85.02	15.75	7.50	9.60	1.78	0.69	43.33
G9	5	74.21	12.40	19.13	61.88	82.02	189.05	71.59	2.25	15.80	19.11	80.89	14.15	7.50	6.72	3.59	0.51	46.59
G10	5	67.31	15.10	21.43	59.80	87.15	181.81	42.05	2.51	12.80	17.70	82.30	11.85	10.00	9.60	2.75	0.39	76.86
G11	5	53.88	11.00	14.20	57.99	72.40	139.95	34.28	7.22	5.00	23.33	76.67	12.6	8.00	9.60	2.72	0.32	82.74
G12	5	67.38	15.80	22.00	68.00	78.26	177.72	67.23	0.68	17.44	14.00	86.00	12.55	8.50	8.64	3.43	0.24	44.29
G13	5	62.58	14.10	19.05	57.26	69.53	125.61	42.05	2.51	11.80	25.80	74.20	14.55	9.50	10.56	2.04	1.05	32.26
G14	5	70.57	12.80	18.70	63.59	77.27	151.56	47.11	2.02	13.13	28.80	71.20	15.4	8.00	7.68	3.08	0.07	70.98
G15	5	70.03	13.00	18.64	71.35	75.28	164.10	61.11	2.44	8.78	21.30	78.70	13.6	8.50	9.60	3.79	0.41	38.25
G16	6	59.12	10.20	17.34	65.51	65.34	115.70	67.61	-0.16	20.80	24.18	75.82	14.4	8.00	7.68	2.39	0.85	41.73
G17	6	52.16	9.70	16.85	61.82	55.80	65.375	55.78	-0.73	20.75	14.22	85.78	17.05	8.00	14.40	3.25	0.27	45.90
G18	6	58.05	9.80	15.79	61.53	63.77	98.25	59.52	0.95	15.52	16.80	83.20	14.9	9.00	7.68	1.85	0.54	37.02

G19	6	54.00	9.50	15.43	59.40	60.92	90.20	55.41	-0.15	20.06	25.79	74.21	13.8	6.50	4.80	3.63	0.28	52.10
G20	6	49.53	11.10	15.45	58.92	60.81	95.13	51.17	1.19	19.25	35.28	64.72	20.85	7.50	5.76	2.79	0.11	33.92
G21	6	32.90	6.00	5.72	49.25	35.19	28.25	44.78	0.74	18.04	32.49	67.51	17.05	7.50	5.76	2.63	0.28	36.38
G22	6	52.84	8.10	12.15	57.75	51.84	61.20	58.68	-1.64	22.29	23.84	76.16	20.8	6.50	8.64	3.51	0.86	43.12
G23	6	47.30	9.60	13.11	53.09	60.48	92.71	56.04	0.79	22.90	27.69	72.31	14.65	8.50	7.68	1.99	0.15	50.34
G24	6	62.19	9.78	16.85	55.73	59.56	92.64	57.67	0.14	24.05	24.35	75.65	13.8	8.00	7.68	2.98	0.78	33.12
G25	6	41.00	7.67	10.29	42.63	34.80	18.50	42.72	0.48	14.34	39.05	60.95	21.6	6.50	9.60	3.82	0.03	40.93
G26	6	61.32	9.50	16.69	57.93	54.41	73.89	63.72	-1.20	23.42	19.34	80.66	15.2	6.00	10.56	2.31	0.01	48.30
G27	6	57.43	9.70	17.71	66.39	64.76	113.00	58.90	-0.13	19.66	29.08	70.92	15.9	8.00	12.48	3.18	0.61	36.91
G28	6	52.63	13.80	18.96	69.11	67.94	130.75	69.67	-0.09	22.89	26.70	73.30	18.15	8.50	8.64	1.75	1.05	45.36
G29	7	64.54	10.70	17.95	59.55	54.71	69.90	57.30	-1.16	19.75	30.68	69.32	13.6	7.50	12.48	3.56	0.26	39.00
G30	7	58.92	10.90	18.03	67.11	61.76	111.11	57.29	0.58	16.91	15.02	84.98	15.6	8.00	5.76	2.71	1.04	51.89
G31	7	59.12	14.00	19.51	68.51	58.60	103.60	39.69	1.62	17.07	12.70	87.30	16.85	7.50	7.68	2.68	0.16	35.36
G32	7	49.26	10.70	16.91	70.37	58.81	102.11	53.36	0.44	21.72	25.01	74.99	18.75	9.00	9.60	3.45	0.62	44.03

Table 1 contd..

Genotype	DG	PH	NOL	CG	PD	ED	BW	L*	a*	b*	DM	M	TSS	NOR	ASC	TFC	FRAP	TPC
G33	7	36.62	6.30	10.72	53.22	46.12	55.94	46.83	0.73	19.97	24.92	75.08	15.6	6.00	8.64	2.01	0.35	39.48
G34	7	58.11	12.20	17.43	60.87	63.39	107.72	51.07	0.34	20.90	24.19	75.81	12.7	7.50	5.76	3.05	0.22	31.35
G35	7	55.70	10.00	14.90	65.82	61.62	105.00	58.77	-0.01	24.68	13.59	86.41	14	7.00	10.56	3.77	0.28	49.96
G36	7	48.05	8.71	12.52	62.05	68.62	124.75	52.24	0.97	19.72	15.31	84.69	12.55	8.00	11.52	2.36	0.15	37.34
G37	7	43.38	7.50	9.73	55.34	49.88	55.75	56.73	1.06	22.88	30.97	69.03	15.25	8.50	6.72	3.23	0.70	46.81
G38	7	38.40	5.00	5.64	65.76	41.85	56.50	59.12	0.26	21.10	25.77	74.23	14.7	7.00	6.72	1.81	0.23	40.50
G39	6	39.41	6.80	10.71	61.62	56.98	85.67	57.44	-0.10	22.97	24.65	75.35	15.1	8.50	8.64	3.60	0.34	52.90
G40	6	52.60	9.70	12.01	57.79	52.72	70.44	50.88	-0.43	21.28	25.39	74.61	14.65	9.00	8.64	2.77	1.21	34.56
G41	6	61.61	11.00	16.31	66.60	62.79	113.21	53.84	1.38	19.85	13.09	86.91	19.4	9.50	6.72	2.64	0.78	36.33
G42	6	53.35	9.60	15.56	50.93	63.41	80.50	54.42	0.56	19.34	33.48	66.52	21.5	8.50	9.60	3.50	1.10	45.63
G43	6	49.46	8.00	14.12	66.78	62.18	109.44	57.65	0.45	18.11	14.57	85.43	15.45	8.00	6.72	1.98	0.09	33.97

G44	6	57.68	12.00	16.13	75.77	69.88	165.75	61.81	0.78	19.55	21.04	78.96	19.85	9.00	9.60	3.01	1.23	48.57
G45	6	66.37	7.60	11.45	72.60	62.09	96.10	52.32	1.87	13.11	23.09	76.91	16.25	8.00	11.52	3.83	0.85	70.98
G46	6	57.02	11.40	17.56	68.73	67.38	128.70	44.52	2.84	16.31	22.01	77.99	14.1	8.00	9.60	2.32	1.08	38.47
G47	6	58.08	7.80	12.22	66.01	57.60	79.65	47.97	2.61	16.08	14.26	85.74	15.9	6.50	7.68	3.20	0.09	51.30
G48	6	54.44	7.50	13.24	63.49	60.55	96.75	47.15	2.63	12.72	20.13	79.87	18.15	7.00	6.72	1.77	0.10	36.91
G49	6	58.62	7.80	10.24	50.70	57.96	68.20	51.51	1.72	14.78	12.88	87.12	11.7	7.50	7.68	3.58	0.50	43.39
G50	6	56.55	9.25	13.52	62.44	72.99	147.00	65.96	0.77	14.88	22.71	77.29	14.25	8.00	7.68	2.74	0.05	48.04
G51	6	48.76	6.33	12.49	56.18	55.29	109.67	52.86	4.24	9.77	21.89	78.11	15.15	7.00	9.60	2.66	0.78	33.39
G52	7	50.46	9.43	13.29	71.63	63.19	98.70	42.68	1.25	16.97	22.72	77.28	14.8	7.50	8.64	3.47	0.92	41.25
G53	7	56.58	7.25	12.09	65.54	60.75	123.79	55.58	4.14	11.87	27.27	72.73	13.9	8.00	6.72	1.97	0.18	44.94
G54	7	48.90	5.17	9.75	54.11	56.68	80.13	48.41	1.94	17.57	22.51	77.49	15.3	8.50	9.60	3.04	0.99	37.18
G55	7	62.72	7.70	12.86	60.87	65.95	125.28	47.70	4.02	9.92	25.79	74.21	15.9	8.50	10.56	3.81	0.48	49.70
G56	8	62.20	10.50	14.14	57.69	85.85	179.00	46.18	1.95	21.42	22.79	77.21	14.15	7.50	10.56	2.33	1.15	32.10
G57	8	59.67	10.33	13.26	61.13	76.39	139.75	44.99	0.84	11.52	29.71	70.29	16.6	8.00	8.64	3.21	0.18	43.33
G58	8	69.35	11.60	17.28	57.03	70.21	139.00	61.04	0.83	19.01	11.47	88.53	13.75	7.50	15.36	1.74	0.11	46.22
G59	5	62.47	13.10	17.93	58.52	72.66	138.38	60.03	-0.93	20.62	27.69	72.31	14	8.50	7.68	3.55	0.75	40.02
G60	5	60.28	10.30	14.44	62.18	53.63	76.50	54.10	1.24	24.16	36.84	63.16	27.3	7.50	9.60	2.72	1.25	52.53
G61	5	55.78	7.11	15.63	61.46	62.40	114.43	38.87	1.75	13.65	24.14	75.86	16.45	8.00	10.56	2.62	0.80	35.90
G62	5	62.89	9.70	14.87	59.65	64.04	123.38	36.96	5.44	8.36	28.32	71.68	19.6	8.50	13.44	3.52	0.88	43.76
G63	5	58.42	16.44	15.77	65.76	66.46	123.25	55.04	2.69	13.53	22.08	77.92	14.8	6.50	11.52	1.94	0.34	67.24
G64	5	58.16	7.70	13.02	72.34	70.83	140.23	60.92	1.02	14.03	27.57	72.43	14.95	7.00	8.64	3.00	0.82	51.14
G65	5	40.97	6.00	12.63	64.73	89.25	232.50	41.40	4.46	3.99	21.51	78.49	12.6	8.50	11.52	3.85	0.53	39.00
G66	5	43.53	6.33	10.36	54.16	54.26	61.23	48.64	1.34	12.31	24.54	75.46	13.15	8.00	9.60	2.29	0.45	47.34

Table 1 contd..

Genotype	DG	PH	NOL	CG	PD	ED	BW	L*	a*	b*	DM	M	TSS	NOR	ASC	TFC	FRAP	TPC
G67	5	65.31	9.40	12.54	65.05	66.09	122.05	48.08	2.00	16.39	20.93	79.07	13.4	8.50	5.76	3.17	0.29	93.97
G68	5	66.12	9.00	14.78	58.73	65.68	111.65	64.93	2.06	15.03	11.91	88.09	14.7	7.50	11.52	1.71	1.00	44.56
G69	5	56.65	8.00	13.54	35.71	33.	11.95	26.50	6.49	5.19	32.18	67.82	20.5	5.50	7.68	3.54	0.61	41.14

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G70	5	62.65	9.00	12.65	33.79	35.20	15.25	28.61	2.51	8.03	31.26	68.74	16.8	5.00	6.72	2.70	0.34	53.39
C1	5	62.93	10.11	16.71	72.03	69.59	142.45	83.81	-0.42	13.97	24.38	75.62	13.36	8.93	11.11	1.776	0.18	41.01
C2	5	62.52	10.34	17.6	75.05	72.79	156.75	82.24	-0.31	13.62	28.63	71.37	15.4	9.50	9.19	2.027	0.86	45.65
C3	5	62.03	10.83	16.83	71.13	70.82	147.32	81.26	-0.01	13.22	26.83	73.17	16.13	7.57	8.78	3.443	0.60	32.25
C4	5	66.36	11.67	18.1	70.64	73.28	155.01	46.08	5.5	10.85	24.52	75.48	16.79	8.57	9.05	3.335	0.40	53.94
C5	5	57.96	11.24	16	64.63	67.11	120.96	49.18	4.38	11.53	20.62	79.38	17.09	6.57	10.15	5.441	0.34	47.42
C6	5	55.27	11.24	15.35	61.08	64.45	139.36	51.71	3.78	11.12	23.49	76.51	17.66	8.93	10.83	5.632	0.88	39.40
Mean ±SE.m	5.83±0.10	58.43±1.22	9.99±0.26	15.67±0.33	62.17±0.95	64.33±1.27	116.98±4.82	54.04±1.36	1.73±0.20	15.77±0.60	22.80±0.76	77.20±0.76	15.88±0.32	7.94±0.12	8.99±0.25	2.92±0.09	0.53±0.04	45.64±1.43
CD at 5%	0.00	9.81	3.15	5.18	15.67	16.46	124.87	0.49	0.28	0.60	0.14	0.14	4.26	1.20	3.78	0.11	0.43	0.22

DG: Days to germination, PH: Plant height (cm), NOL: Number of leaves, CG: Collar girth (mm), PD: Polar diameter (mm), ED: Equatorial diameter (mm), BW: Bulb weight (g), L*: Colorimeter (L*), a*: Colorimeter (a*), b*: Colorimeter (b*), DM: Dry matter (%), M: Moisture (%), TSS: Total Soluble Solids (0 Brix), NOR: Number of rings, ASC: Ascorbic acid (mg/100g FW), TFC: Total flavonoids (mg QE/g FW), FRAP: Total antioxidant (mg AAE/g), TPC: Total phenols (mg GAE /g)

Table 2. Comparison of mean and genetic variability components of onion genotypes for morphological traits in the rabi season

Traits	Genotypes/Checks	Mean ± SEm	Min.	Max.	CV (%)	GCV (%)	PCV (%)	h2bs	GA	GAM (%)
Days to Germination	Genotypes	5.9±0.10	5.00	8.00	0.00	14.94	14.94	100	1.80	30.81
	Checks	5.00±0.0	5.00	5.00						
Plant height (cm)	Genotypes	67.44±1.09	32.9	74.21	5.34	14.94	15.90	88.28	16.72	28.96
	Checks	61.18±1.61	55.27	66.36						
Number of leaves	Genotypes	9.90±0.30	5.00	16.44	9.82	22.98	25.11	83.78	4.33	43.89
	Checks	10.91±0.24	10.11	11.67						
Collar girth (mm)	Genotypes	15.15±0.42	5.00	22.00	10.54	20.4	23.12	77.9	5.67	37.15
	Checks	16.77±0.41	15.35	18.1						

Polar diameter (mm)	Genotypes	61.58±0.96	33.79	82.05	7.80	10.08	12.92	60.9	10.09	16.23
	Checks	69.09±2.12	61.08	75.05						
Equatorial diameter (mm)	Genotypes	63.87±1.46	33.99	89.25	7.99	17.08	18.94	81.24	20.43	31.75
	Checks	69.67±1.39	64.45	73.28						
Bulb weight (g)	Genotypes	113.20±5.48	11.95	232.50	31.88	19.27	39.27	24.08	22.82	19.51
	Checks	143.64±5.32	120.96	156.75						

GCV= Genotypic co-efficient of variation; PCV= Phenotypic co-efficient of variation; h2 =heritability in broad sense; GA=Genetic Advance; GAM=Genetic advance over percent mean

Table 3. Comparison of mean and genetic variability components of onion genotypes for biochemical traits in rabi season

Traits	Genotypes/Checks	Mean ± SEm	Min.	Max.	CV (%)	GCV (%)	PCV (%)	h2bs	GA	GAM (%)
Colorimeter (L^*)	Genotypes	53.04±1.28	26.5	81.51	0.27	19.84	19.84	99.98	22.11	40.92
	Checks	65.71±7.52	46.08	83.81						
Colorimeter (a^*)	Genotypes	1.58±0.22	-1.64	7.22	4.94	97.86	98.54	99.77	3.80	219.82
	Checks	2.15±1.09	-0.42	5.5						
Colorimeter (b^*)	Genotypes	16.06±0.64	3.62	24.68	0.51	33.76	33.76	99.98	10.98	69.64
	Checks	12.39±0.56	10.85	13.97						
Dry matter (%)	Genotypes	15.86±0.33	11.47	39.05	0.18	27.14	27.14	99.99	12.95	55.99
	Checks	24.75±0.75	20.62	28.63						
Moisture (%)	Genotypes	77.00±0.82	60.95	88.53	0.06	8.17	8.17	99.99	12.95	16.84
	Checks	75.26±1.13	71.37	79.38						
Total Soluble Solids (^{0} Brix)	Genotypes	15.86±0.34	11.7	27.3	8.57	15.7	17.91	76.89	4.51	28.41
	Checks	16.07±0.63	13.36	17.66						
Number of rings	Genotypes	7.9±0.12	5.00	10.00	4.78	11.71	12.68	85.33	1.77	22.31
	Checks	8.35±0.44	6.57	9.50						
Ascorbic acid (mg/100g FW)	Genotypes	8.91±0.25	4.80	15.36	13.09	19.51	23.72	67.65	2.98	33.1
	Checks	9.85±0.40	8.58	11.11						
Total flavonoids (mg QE/g FW	Genotypes	2.86±0.08	1.71	3.86	1.10	22.49	22.52	99.72	1.35	46.34
	Checks	3.61±0.67	1.78	5.63						
Total antioxidant (mg AAE/g)	Genotypes	0.53±0.04	0.01	1.25	26.11	60.87	66.3	84.3	0.61	115.29
	Checks	0.54±0.12	0.18	0.88						
Total phenols (mg GAE /g FW)	Genotypes	45.48±1.40	31.19	82.74	0.16	25.96	25.96	99.99	24.26	53.55
	Checks	43.27±3.05	32.25	53.94						

GCV= Genotypic co-efficient of variation; PCV= Phenotypic co-efficient of variation; h2 =heritability in broad sense; GA=Genetic Advance; GAM=Genetic advance over percent mean

RESULTS AND DISCUSSION

Morphological and yield-related traits

The evaluated onion (Allium cepa L.) genotypes exhibited considerable variability in morphological traits during the Rabi season. Days to germination averaged 5.90 days (5.00–8.00 days), with GCV and PCV values of 14.94% each, heritability of 100.00% and genetic advance as a percentage of the mean (GAM) of 30.81%. These estimates suggest consistent differences among the evaluated genotypes. Plant height averaged 67.44 cm (32.90-74.21 cm), with GCV of 14.94%, PCV of 15.90%, heritability of 88.28% and GAM of 28.96%. Dangi et al. (2018) identified plant height, leaf length and pseudostem diameter as major contributors to the first principal component, indicating their importance in distinguishing onion genotypes. Number of leaves averaged 9.90 (5.00-16.44), with GCV of 22.98%, PCV of 25.11%, heritability of 83.78% and GAM of 43.89%. The combination of high heritability and GAM indicates potential for selection, consistent with Dangi et al. (2018), who reported high heritability and genetic advance for number of leaves, and Parmar et al. (2018), who reported high heritability for this trait. Collar girth averaged 15.15 mm (5.00-22.00 mm), with GCV of 20.40%, PCV

of 23.12%, heritability of 77.90% and GAM of 37.15%. These estimates indicate considerable relative variability and potential for selection. Dewangan and Sahu (2012) reported high heritability coupled with high genetic advance for collar height in their Kharif onion material, suggesting that this trait could be useful in selection under their experimental conditions. However, collar height and collar girth are distinct measurements. Polar diameter averaged 61.58 mm (33.79-82.05 mm), with GCV of 10.08%, PCV of 12.92%, heritability of 60.90% and GAM of 16.23%. Its relatively lower GAM indicates less expected selection progress relative to traits with higher GAM. Khosa and Dhatt (2013) reported high heritability for polar diameter, whereas Parmar et al. (2018) reported moderate heritability for this trait, illustrating that genetic estimates vary among populations and environments. Equatorial diameter averaged 63.87 mm (33.99-89.25 mm), with GCV of 17.08%, PCV of 18.94%, heritability of 81.24% and GAM of 31.75%. The combination of high heritability and GAM indicates potential for selection. Narayan et al. (2019) documented variation in equatorial diameter among long-day onion genotypes, while Yogita et al. (2023) investigated correlations and path relationships among traits in onion genotypes, supporting the importance of evaluating bulb dimensions alongside other yield components. Bulb weight averaged 113.20 g (11.95-232.50 g), with GCV of 19.27%, PCV of 39.27%, heritability of 24.08% and GAM of 19.51%. The large difference between PCV and GCV, together with low heritability, indicates that the estimated phenotypic variation substantially exceeded the estimated genotypic variation, making selection based on bulb weight alone less reliable in the present population. In contrast, Parmar et al. (2018) reported high heritability and genetic advance for bulb weight, whereas Khosa and Dhatt (2013) reported moderate heritability, demonstrating that selection potential differs among onion populations. Dewangan and Sahu (2012) investigated correlations and path relationships among yield-related traits in Kharif onion. Therefore, bulb weight should be evaluated alongside other yield components in the present material. Overall, the combination of high heritability and GAM for plant height, number of leaves, collar girth and equatorial diameter suggests that these traits may be useful selection criteria in the evaluated population.

Biochemical and Quality Traits

The biochemical composition and bulb-quality attributes of the evaluated onion (Allium cepa L.) genotypes showed considerable variation during the Rabi season, with differences in colour parameters, dry matter, nutritional constituents and antioxidant activity. Bulb colour parameters L*, a* and b* recorded mean values of 53.04, 1.58 and 16.06, respectively. The GCV and PCV were 19.84% for L*, 97.86% and 98.54% for a* and 33.76% for b*. Broad-sense heritability was very high for L* (99.98%), a* (99.77%) and b* (99.98%), with GAM values of 40.92%, 219.82% and 69.64%, respectively. The high heritability and GAM indicate substantial selection potential for colour characteristics in the evaluated population. Lee et al. (2015) documented differences in colour-associated phytochemical characteristics among white, yellow and red onion cultivars, while Chandel et al. (2024) reported diversity in morphological and biochemical traits among Indian onion genotypes. Dry matter content ranged from 11.47 to 39.05%, with a mean of 15.86% and GCV and PCV values of 27.14%; moisture content ranged from 60.95 to 88.53%, averaging 77.00%, with GCV and PCV values of 8.17%. Both traits exhibited very high heritability, with estimates of 99.99% each. Dry matter recorded a GAM of 55.99%, whereas moisture content recorded a GAM of 16.84%. The higher GAM for dry matter suggests greater relative scope for selection for this trait than for moisture content. Dangi et al. (2018) identified Arka Kalyan as having the highest dry matter content (15.70%) among the genotypes they evaluated and reported a positive correlation between dry matter and total soluble solids. Islam et al. (2019) also documented variation in bulb-quality traits among onion genotypes. TSS ranged from 11.70 to 27.30 °Brix, with a mean of 15.86 °Brix, while GCV and PCV were 15.70% and 17.91%, respectively. Heritability was 76.89%, with GAM of 28.41%, indicating moderate-to-high selection potential, although the greater PCV than GCV suggests that phenotypic variation exceeded estimated genotypic variation. Islam et al. (2019) reported TSS values ranging from 10.13 to 16.65 °Brix, demonstrating variation among onion materials. The number of rings ranged from 5 to 10, with a mean of 7.90 and GCV and PCV values of 11.71% and 12.68%, respectively. Heritability was 85.33%, and GAM was 22.31%. The relatively modest GCV and GAM indicate lower relative variability and expected selection progress than for traits such as dry matter and FRAP, despite the high heritability. Ascorbic acid content ranged from 4.80 to 15.36 mg/100 g fresh weight, averaging 8.91 mg/100 g, with GCV and PCV values of 19.51% and 23.72%, respectively. Heritability was 67.65%, with GAM of 33.10%, indicating useful selection potential, although the difference between GCV and PCV suggests that phenotypic variability exceeded estimated genotypic variability. Total flavonoid content ranged from 1.71 to 3.86 mg QE/g fresh weight, with a mean of 2.86 mg QE/g and GCV and PCV values of 22.49% and 22.52%, respectively. The trait recorded very high heritability (99.72%) and GAM of 46.34%, suggesting substantial potential for selection for flavonoid content in the evaluated genotypes. Kaur et al. (2009) reported significant differences in flavonoid content among ten onion cultivars, with Pusa Red, Sel-402, H-44 and N-53 recording high values in their study. Islam et al. (2019) likewise documented variation in flavonoid content among onion varieties. Total phenolic content ranged from 31.19 to 82.74 mg GAE/g fresh weight, with a mean of 45.48 mg GAE/g and GCV and PCV values of 25.96%. Heritability was 99.99%, with GAM of 53.55%, indicating considerable relative selection potential for this trait. Dangi et al. (2018) recorded the highest total phenolic content in genotype Juni (36.96 mg/g fresh weight), while Kaur et al. (2009) reported significant differences in phenolic content among cultivars, with red cultivars generally belonging to the higher-phenolic group in their experiment. These comparisons support the importance of evaluating phenolic content when characterising onion germplasm, although differences in extraction procedures and reporting units must be considered when comparing numerical values. FRAP antioxidant activity ranged from 0.01 to 1.25 mg AAE/g, with a mean of 0.53 mg AAE/g and GCV and PCV values of 60.87% and 66.30%, respectively. It recorded heritability of 84.30% and GAM of 115.29%, representing the highest GAM among the reported biochemical traits. The combination of high relative variability, high heritability and high GAM indicates substantial potential for selection for antioxidant activity, although validation in additional environments would be needed to assess the stability of genotype performance. Kaur et al. (2009) found a positive association between total phenolic content and FRAP antioxidant activity across the cultivars and years they evaluated. Sharma et al. (2014) also

reported cultivar-dependent differences in phenolic content, flavonoids and antioxidant activity among 18 Korean onion cultivars. Together, these findings suggest that the evaluated onion genotypes offer opportunities for identifying material with desirable biochemical and quality characteristics.

4. CONCLUSION

The present investigation revealed considerable genetic variability among onion (Allium cepa L.) genotypes for morphological and biochemical traits during the Rabi season. The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as a percentage of the mean (GAM) indicated differential selection potential among the traits. Among the morphological characters, number of leaves and collar girth recorded high GAM values of 43.89% and 37.15%, respectively. Among the biochemical traits, FRAP antioxidant activity exhibited the highest GAM (115.29%), followed by dry matter content (55.99%), total phenolic content (53.55%) and total flavonoid content (46.34%). The high heritability coupled with high GAM observed for dry matter, total phenolic content and total flavonoid content indicates considerable scope for improvement through selection. Therefore, genotypes possessing desirable morphological characteristics and superior biochemical quality can be further evaluated and exploited in onion breeding programmes aimed at improving bulb quality and antioxidant potential. Further evaluation across seasons and locations is necessary to confirm the stability of these traits and identify promising genotypes for future crop improvement.

5. Future Scope

The genotypes exhibiting desirable morphological and biochemical characteristics can be utilised as potential parental material in onion improvement programmes. Particular emphasis may be given to selecting genotypes with high dry matter, total phenolic content, total flavonoid content and FRAP antioxidant activity, together with desirable bulb traits. Genotypes contrasting in these characteristics may be used in hybridisation programmes to combine favourable attributes and develop improved breeding populations. Further evaluation across multiple seasons and locations, followed by validation of the stability of important traits, would help identify superior genotypes for developing onion varieties with improved bulb quality, nutritional value and antioxidant potential.

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