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Genetic Variability and Performance Assessment of Onion (*Allium cepa* L.) Genotypes for Yield and Quality Traits

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Abstract— *This study assessed genetic variability and performance of 50 onion (Allium cepa L.) genotypes for 18 quantitative traits during the rabi seasons of 2023-24 and 2024-25 at Dharwad, Karnataka, India. Significant genotypic variability was observed across traits, with high-performing genotypes like NHRDF Red-2 (50.6 t/ha), NHRDF Red-4 (48.5 t/ha) and Balichakra-R (47.2 t/ha) for bulb yield. High genotypic and phenotypic coefficients of variation (GCV and PCV) were recorded for bulb neck thickness (15.28%, 19.38%), bulb yield per plot (10.86%, 11.50%) leaf area (9.92%, 10.95%). Broad-sense heritability (h^2_bs > 80%) with high genetic advance as percent of mean (GAM > 18%) was observed for bulb yield per plot (89%, 21.12%), leaf area (82%, 18.49%), leaf area index (LAI) (82%, 18.47%) and number of rings per bulb (88%, 19.86%), indicating additive gene action and selection potential. Low heritability for days to maturity (31%, 2.12%) and total soluble solids (TSS) (16%, 3.15%) suggested environmental influence. Negative heritability for number of leaves per plant (-10%, -2.53%) and premature bolting (-11%, -2.40%) indicated data anomalies or environmental dominance. These findings highlight genotypes and traits suitable for breeding high-yielding, adaptable onion varieties.*

Keywords— ***Onion, Genetic variability, Heritability, Yield traits, Performance evaluation***

I. INTRODUCTION

Onion (*Allium cepa* L.), a diploid (2n = 16) biennial herb of the Alliaceae family, is a globally significant vegetable crop originating from Central Asia, with the Mediterranean as a secondary center of diversity (McCollum, 1976). It ranks fourth among vegetables worldwide, valued for its nutritional content (86.6 g moisture, 1.2 g protein, 11.1 g carbohydrates per 100 g) and medicinal properties, including anti-carcinogenic and antioxidant effects due to quercetin flavonoids and sulfur compounds (Sahu *et al*., 2018; Griffiths, 2002; Gopalakrishnan *et al*., 2007). In India, onion cultivation spans 1.537 million hectares, producing 24.212 million tonnes with a productivity of 16.10 t/ha, while Karnataka contributes 0.255 million hectares and 2.049 million tonnes at 14.17 t/ha (Anonymous, 2024). India's productivity lags behind countries like the USA (55.95 t/ha) due to limited use of F1 hybrids and environmental constraints (Parmar *et al*., 2018).

Onion is photo-thermo-sensitive, requiring specific day lengths (12-13 hours for rabi varieties) and temperatures (12.8-23°C for vegetative growth, 15.5-25°C for bulbing). Its biennial cycle, high heterozygosity and large genome (16.3 Gbp) complicate genetic research (Chattoo and Angrej, 2015). Understanding genetic variability, heritability and trait performance is essential for breeding programs to meet the projected demand of 24.62 million tonnes by 2050 (Yogita *et al*., 2023). This study evaluated 50 onion genotypes for performance and genetic variability in 18 traits to identify superior lines for breeding.

II. MATERIALS AND METHODS

Fifty onion genotypes from ICAR-Directorate of Onion and Garlic Research (DOGR), National Horticultural Research and Development Foundation (NHRDF), Indian Institute of Horticultural Research (IIHR), Anand Agricultural University (AAU) and local Karnataka collections were studied, encompassing red, light red, dark red and white bulb types (Table 1).

Experiments were conducted during rabi seasons (2023-24 and 2024-25) at the Main Agricultural Research Station, Dharwad, Karnataka (15°26'N, 75°07'E, 678 m ASL) with black clay soil (pH 7.5). A randomized complete block design (RCBD) with three replications was used. Seedlings were transplanted at 45-50 days in 3 m × 2 m plots with 15 × 10 cm spacing. Standard practices included 100:50:50 kg NPK/ha, irrigation and pest management. Meteorological data showed average rainfall of 510.70 mm (2023-24) and 976.10 mm (2024-25), temperatures of 18.95-31.85°C and 18.89-31.17°C and relative humidity of 55.77-76.76% and 57.58-81.14%.

Eighteen traits were recorded on five plants per replication: plant height (cm), number of leaves/plant, leaf area (cm²), LAI, days to maturity, premature bolting (%), bulb polar and equatorial diameters (cm), bulb shape index, bulb neck thickness (cm), number of rings/bulb, bulb dry matter (g), TSS (°Brix), average bulb weight (g), bulb yield per plot (kg) and per hectare (t), purple blotch incidence (%) and thrips incidence (no./plant).

Analysis of variance (ANOVA) followed Fisher's method (Fisher and Yates, 1963). Genotypic (GCV) and phenotypic (PCV) coefficients of variation were estimated per Burton and De Vane (1953) and Sivasubramanian and Menon (1973). Broad-sense heritability (h^2_bs) was calculated using Lush (1940) and genetic advance (GA) and GAM followed Johnson *et al*. (1955). Data were analyzed using standard statistical software.

Table 1. Pooled analysis of variance for yield and yield attributing traits of onion genotypes at Dharwad during rabi-2023-24 and 2024-25

Sl. No.	Source of variation/ parameters	Means			S.Em±	CD (5%)
		Replication	Genotypes	Error		
	Degrees of freedom	**1**	**49**	**49**		
1.	Plant height (cm)	449.86	40.58*	6.05	1.74	4.94
2.	Number of leaves per plant	0.04	0.87*	1.07	0.73	2.08
3.	Leaf area (cm^2)	39315.75	4208.46*	417.31	14.44	41.05
4.	Leaf area index	1.74	0.19*	0.02	0.10	0.27
5.	Days to maturity (days)	28.09	12.43*	6.48	1.80	5.11
6.	Pre-mature bolting (%)	5.29	2.18*	0.88	0.66	1.88
7.	Bulb polar diameter (cm)	1182.67	23.11*	28.83	3.80	10.79
8.	Bulb equatorial diameter (cm)	1028.29	23.63*	5.29	1.63	4.62
9.	Bulb shape index	0.01	0.02*	0.00	0.04	0.11
10.	Bulb neck thickness (cm)	0.02	0.05*	0.01	0.07	0.21
11.	Number of rings per bulb	0.25	1.72*	0.55	0.52	1.48
12.	Bulb dry matter content (g)	0.43	2.41*	0.40	0.45	1.27
13.	Total soluble solid (^{0}B)	12.62	3.47*	0.20	0.31	0.89
14.	Average weight of bulb (g)	8447.26	92.55*	65.74	5.73	16.29
15.	Bulb yield per plot (kg)	0.20	0.39*	0.02	0.11	0.30
16.	Bulb yield per hectare (t)	19.70	39.24*	2.25	1.06	3.01
17.	Purple blotch incidence	65.61	0.76*	0.68	0.58	1.66
18.	Thrips incidence (Nymphs)	0.01	15.54*	0.00	0.01	0.03

* Significant at 5 % level of significance

III. RESULTS AND DISCUSSION

ANOVA revealed significant genotypic differences ($P<0.05$) for all 18 traits in two years and pooled data (Tables 1), confirming substantial genetic variability, consistent with Malik *et al*. (2024) and Gupta *et al*. (2024). Non-significant replication effects and low error variances indicate experimental reliability. The pooled analysis highlighted consistent genotypic effects across seasons, supporting robust genetic assessments (Chand *et al*., 2024).

Mean performances across genotypes partially truncated in the document (Table 2-6) showed significant variation, aligning with Rani *et al*. (2024) and Sharma and Khadda (2024).

Table 2 Mean performance of onion genotypes for the plant height and number of leaves per plant during rabi-2023-24 and 2024-25

Sl.No.	Genotypes	Plant Height (cm)	No. of Leaves/ Plant	Leaf Area (cm)	Leaf Area Index	Days to maturity	Bulb polar diameter	Bulb equatorial diameter	Bulb shape index
1	Arka Bheem	52.21	8.00	424.27	2.83	97.75	4.87	5.30	0.86
2	Balichakra-W	52.65	8.50	492.90	3.29	100.75	4.64	5.18	0.82
3	Bagdal Local	56.53	9.00	437.97	2.92	94.25	5.31	5.72	0.85
4	Arka Kalyan	43.63	8.75	486.53	3.24	93.00	4.81	5.65	0.91
5	Balichakra-R	47.90	9.00	467.52	3.12	96.50	5.16	5.32	0.97
6	NHRDF Red	49.13	7.25	353.65	2.36	97.50	4.86	5.39	0.96
7	Telagi -L	43.90	7.50	501.63	3.34	96.00	4.68	5.49	0.94
8	Telagi -W	41.23	8.75	442.12	2.95	96.50	4.81	5.79	0.93
9	Bellary Red	53.78	7.50	502.04	3.35	95.00	5.04	4.78	1.00
10	GWO-1	52.98	7.50	390.46	2.60	96.50	4.86	5.41	0.74
11	GJRO-11	56.10	9.25	397.77	2.65	96.25	5.26	5.45	0.85
12	GJWO-3	54.10	7.25	443.93	2.96	92.50	5.09	5.84	0.78
13	Bhima Red	45.83	8.25	385.52	2.57	92.25	4.29	5.64	0.78
14	DOGR-1770	53.93	6.75	402.70	2.68	93.25	5.07	5.69	0.84
15	DOGR-1760	52.15	8.50	378.36	2.52	92.50	4.98	5.54	0.86
16	DOGR-1761	53.18	8.25	397.81	2.65	91.50	5.16	5.84	0.91
17	DOGR-1771	50.08	8.50	375.02	2.50	91.25	4.88	6.19	0.82
18	DOGR-1773	56.23	7.75	446.27	2.98	91.75	5.53	5.70	0.95
19	DOGR-1774	47.00	7.75	407.84	2.72	89.00	4.59	5.42	0.84
20	Bhima Super	49.78	7.50	463.93	3.09	90.50	4.96	5.81	0.88
21	Bhima Raj	55.85	7.50	470.70	3.14	92.00	5.41	5.57	0.98
22	Bhima Shakti	52.40	7.75	493.24	3.29	92.75	5.27	5.84	0.87
23	Bhima Light Red	40.00	8.25	502.23	3.35	94.00	4.58	5.74	0.92
24	DOGR-1772	45.05	7.75	473.57	3.16	92.25	4.90	6.02	0.90
25	DOGR-1769	48.18	8.50	480.42	3.20	96.25	4.87	5.70	0.93
26	DOGR-1768	50.35	8.75	453.82	3.03	93.75	4.80	4.93	0.93
27	Bhima Dark Red	49.35	8.00	405.16	2.70	90.50	4.46	5.13	0.78
28	Bhima Kiran	55.83	8.50	489.43	3.26	99.50	5.05	5.24	0.92

29	W-364 GP	45.90	9.00	455.59	3.04	93.50	4.27	5.97	0.66
30	Bhima Shweta	50.63	9.75	435.27	2.90	91.75	4.30	5.31	0.71
31	W-405	42.33	8.25	410.34	2.74	95.50	4.03	5.08	0.81
32	Bhima Shubra	49.73	9.00	416.73	2.78	91.00	4.82	4.96	0.95
33	Bhima Safed	56.43	10.00	441.21	2.94	94.25	4.85	5.07	0.80
34	W-310-GP	50.30	8.50	416.36	2.78	92.50	4.55	5.97	0.71
35	W-344	45.40	9.00	411.02	2.74	94.25	4.55	5.51	0.84
36	W-355	53.53	8.25	366.73	2.44	95.50	4.80	5.84	0.73
37	W-361	47.70	7.50	406.44	2.71	94.00	4.58	5.79	0.75
38	W-504	48.38	8.25	373.49	2.49	95.00	4.80	6.33	0.74
39	W-448	49.65	8.25	523.60	3.49	94.75	5.00	6.08	0.80
40	W-125-GP	44.73	8.50	442.50	2.95	94.00	4.40	5.95	0.77
41	W-210-GP	49.60	8.25	428.17	2.85	94.00	5.02	6.11	0.71
42	W-203-GP	50.68	8.50	432.46	2.88	94.25	4.64	5.44	0.80
43	W-408	43.60	8.00	358.32	2.39	93.00	4.12	5.60	0.74
44	NHRDF Furasangi	44.15	7.75	459.83	3.07	96.50	4.53	5.57	0.91
45	AFLR	50.95	8.00	513.20	3.42	99.25	5.36	5.48	0.95
46	NHRDF Red-4	48.13	7.75	376.41	2.51	95.00	4.99	5.42	0.79
47	NHRDF Red-2	50.95	9.25	452.30	3.02	93.25	4.74	5.02	0.88
48	AFDR	39.18	8.50	449.51	3.00	93.75	4.35	5.43	1.04
49	Arakera local	44.55	9.00	488.52	3.26	97.50	4.38	5.37	0.80
50	N-53	48.40	8.25	526.58	3.51	98.00	5.12	5.62	0.89
	Grand mean	**49.28**	**8.28**	**439.03**	**2.93**	**94.32**	**4.81**	**5.56**	**0.85**
	S.Em±	**1.74**	**0.73**	**14.44**	**0.10**	**1.80**	**3.80**	**1.63**	**0.04**
	CD (5%)	**4.94**	**2.08**	**41.05**	**0.27**	**5.11**	**10.79**	**4.62**	**0.11**

Table 3. Mean performance of onion genotypes for the bulb neck thickness,bulb dry matter and TSS during rabi-2023-24 and 2024-25

Sl. No.	Genotypes	Bulb neck thickness			Bulb dry matter			TSS		
		23-24	24-25	Pooled	23-24	24-25	Pooled	23-24	24-25	Pooled
1	Arka Bheem	0.90	0.93	0.92	14.21	13.39	13.80	13.10	13.75	13.43
2	Balichakra-W	1.11	1.04	1.08	15.57	15.83	15.70	16.05	15.34	15.70
3	Bagdal Local	0.95	0.82	0.89	15.13	15.37	15.25	11.75	13.34	12.55
4	Arka Kalyan	0.72	0.77	0.75	15.90	18.18	17.04	13.10	13.76	13.43
5	Balichakra-R	0.89	0.77	0.83	16.21	16.46	16.34	11.80	12.39	12.10
6	NHRDF Red	0.42	0.76	0.59	14.97	16.73	15.85	15.65	15.43	15.54
7	Telagi -L	0.61	0.52	0.57	15.25	15.49	15.37	11.70	12.81	12.26
8	Telagi -W	1.01	0.87	0.94	14.54	14.77	14.66	11.50	12.07	11.79
9	Bellary Red	0.92	0.79	0.86	15.23	15.47	15.35	12.50	13.13	12.82
10	GWO-1	0.39	0.73	0.56	15.94	16.19	16.07	12.35	12.97	12.66

11	GJRO-11	0.96	0.83	0.90	15.59	15.83	15.71	14.60	14.85	14.73
12	GJWO-3	1.09	0.94	1.02	15.13	15.37	15.25	14.85	15.59	15.22
13	Bhima Red	0.82	0.91	0.87	14.49	14.72	14.61	11.30	11.87	11.59
14	DOGR-1770	0.80	0.69	0.75	13.91	14.13	14.02	9.80	10.29	10.05
15	DOGR-1760	1.04	0.90	0.97	12.53	12.73	12.63	10.65	11.19	10.92
16	DOGR-1761	1.08	0.93	1.01	15.89	16.14	16.02	10.95	10.97	10.96
17	DOGR-1771	0.69	0.75	0.72	18.14	18.42	18.28	12.95	13.60	13.28
18	DOGR-1773	1.15	1.00	1.08	13.20	13.41	13.31	12.15	12.76	12.46
19	DOGR-1774	0.79	0.83	0.81	14.25	14.47	14.36	11.65	12.24	11.95
20	Bhima Super	1.13	0.98	1.06	13.89	14.11	14.00	12.90	13.54	13.22
21	Bhima Raj	1.09	1.07	1.08	15.05	15.28	15.17	10.35	10.87	10.61
22	Bhima Shakti	1.12	1.00	1.06	16.93	17.19	17.06	11.20	13.26	12.23
23	Bhima Light Red	1.02	0.88	0.95	14.51	14.74	14.63	12.05	12.65	12.35
24	DOGR-1772	1.01	0.95	0.98	13.25	13.46	13.36	13.10	13.76	13.43
25	DOGR-1769	0.87	0.91	0.89	15.09	15.33	15.21	10.60	11.13	10.87
26	DOGR-1768	0.82	0.81	0.82	14.39	14.61	14.50	10.50	11.03	10.77
27	Bhima Dark Red	0.91	0.83	0.87	15.73	15.97	15.85	9.50	12.98	11.24
28	Bhima Kiran	1.08	0.93	1.01	14.59	14.82	14.71	9.55	12.03	10.79
29	W-364 GP	0.98	0.90	0.94	14.55	14.78	14.67	11.80	12.39	12.10
30	Bhima Shweta	0.73	0.84	0.79	14.47	14.20	14.34	12.75	14.39	13.57
31	W-405	1.08	0.93	1.01	17.59	15.86	16.73	11.10	11.65	11.38
32	Bhima Shubra	0.42	0.71	0.57	14.94	15.17	15.06	14.10	14.31	14.21
33	Bhima Safed	0.97	0.84	0.91	14.91	15.14	15.03	13.10	13.76	13.43
34	W-310-GP	1.11	1.02	1.07	16.80	16.59	16.70	11.70	12.29	12.00
35	W-344	0.89	0.76	0.83	15.11	15.35	15.23	10.75	11.79	11.27
36	W-355	1.08	1.15	1.12	16.51	16.27	16.39	11.75	12.34	12.05
37	W-361	1.20	1.07	1.14	17.09	15.36	16.23	13.40	14.07	13.74
38	W-504	1.09	1.08	1.09	16.01	14.76	15.39	13.65	14.33	13.99
39	W-448	0.80	0.84	0.82	16.03	16.28	16.16	12.15	12.76	12.46
40	W-125-GP	0.60	0.75	0.68	15.22	15.46	15.34	13.00	13.65	13.33
41	W-210-GP	0.54	0.86	0.70	15.41	15.67	15.54	12.90	13.54	13.22
42	W-203-GP	0.57	0.69	0.63	16.02	18.81	17.42	12.40	13.02	12.71
43	W-408	0.57	0.94	0.76	16.85	15.61	16.23	11.80	12.36	12.08
44	NHRDF Furasangi	0.88	0.76	0.82	13.81	16.05	14.93	13.15	13.81	13.48
45	AFLR	0.84	0.72	0.78	15.65	14.39	15.02	12.50	13.13	12.82
46	NHRDF Red-4	1.02	0.88	0.95	14.60	15.33	14.97	11.95	12.55	12.25
47	NHRDF Red-2	1.01	0.92	0.97	15.65	13.86	14.76	11.35	11.92	11.64
48	AFDR	0.91	0.78	0.85	13.25	13.97	13.61	10.80	11.34	11.07
49	Arakera local	0.81	0.70	0.76	14.94	15.17	15.06	11.15	11.71	11.43
50	N-53	0.97	0.84	0.91	16.25	15.00	15.63	14.45	14.66	14.56
	Grand mean	**0.89**	**0.86**	**0.88**	**15.22**	**15.35**	**15.29**	**12.20**	**12.91**	**12.55**
	S.Em±	**0.08**	**0.09**	**0.07**	**0.90**	**0.96**	**0.45**	**0.86**	**0.93**	**0.31**

	CD (5%)	**0.23**	**0.26**	**0.21**	**2.57**	**2.72**	**1.27**	**2.44**	**2.64**	**0.89**

Table 4. Mean performance of onion genotypes for the bulb yield parameters during rabi-2023-24 and 2024-25

Sl. No.	**Genotypes**	**Average weight of bulb**			**Bulb yield per plot (kg)**			**Bulb yield (t/ ha)**		
		23-24	**24-25**	**Pooled**	**23-24**	**24-25**	**Pooled**	**23-24**	**24-25**	**Pooled**
1	Arka Bheem	74.80	63.43	69.12	3.39	3.34	3.37	33.94	33.37	33.66
2	Balichakra-W	75.55	57.65	66.60	3.45	3.28	3.37	34.50	32.77	33.64
3	Bagdal Local	72.30	55.18	63.74	4.26	3.75	4.01	42.58	37.54	40.06
4	Arka Kalyan	67.80	61.90	64.85	4.14	4.33	4.24	41.37	43.32	42.35
5	Balichakra-R	84.15	57.38	70.77	4.87	4.49	4.68	48.69	44.94	46.82
6	NHRDF Red	80.95	69.13	75.04	3.79	3.75	3.77	37.90	37.49	37.70
7	Telagi -L	81.70	75.35	78.53	3.91	3.93	3.92	39.14	39.33	39.24
8	Telagi -W	91.40	65.90	78.65	2.96	3.20	3.08	29.61	31.96	30.79
9	Bellary Red	73.80	60.38	67.09	4.32	4.17	4.25	43.23	41.70	42.47
10	GWO-1	76.00	66.85	71.43	4.37	4.14	4.26	43.70	41.36	42.53
11	GJRO-11	68.40	56.88	62.64	4.15	4.00	4.08	41.52	39.95	40.74
12	GJWO-3	80.75	64.20	72.48	3.23	3.37	3.30	32.31	33.71	33.01
13	Bhima Red	91.90	61.28	76.59	4.08	4.18	4.13	40.82	41.79	41.31
14	DOGR-1770	92.90	69.68	81.29	4.24	3.94	4.09	42.44	39.38	40.91
15	DOGR-1760	78.95	88.45	83.70	4.59	4.38	4.49	45.94	43.79	44.87
16	DOGR-1761	76.65	69.33	72.99	4.44	4.14	4.29	44.42	41.39	42.91
17	DOGR-1771	79.10	54.30	66.70	4.05	3.76	3.91	40.49	37.59	39.04
18	DOGR-1773	83.85	61.20	72.53	3.94	3.74	3.84	39.41	37.36	38.39
19	DOGR-1774	81.60	66.85	74.23	4.15	4.01	4.08	41.52	40.13	40.83
20	Bhima Super	82.05	76.90	79.48	4.30	4.01	4.16	43.05	40.15	41.60
21	Bhima Raj	85.40	69.33	77.37	4.54	4.64	4.59	45.42	46.42	45.92
22	Bhima Shakti	81.70	74.58	78.14	4.37	4.12	4.25	43.65	41.25	42.45
23	Bhima Light Red	74.60	57.18	65.89	3.90	4.01	3.96	39.05	40.07	39.56
24	DOGR-1772	75.55	60.43	67.99	3.98	4.18	4.08	39.81	41.83	40.82
25	DOGR-1769	77.20	65.45	71.33	4.52	4.10	4.31	45.21	41.00	43.11
26	DOGR-1768	83.45	78.10	80.78	3.40	3.34	3.37	34.04	33.38	33.71
27	Bhima Dark Red	84.95	68.98	76.97	3.45	3.51	3.48	34.46	35.13	34.80
28	Bhima Kiran	94.25	65.25	79.75	4.57	3.98	4.28	45.73	39.81	42.77
29	W-364 GP	96.60	71.18	83.89	3.65	4.03	3.84	36.53	40.29	38.41
30	Bhima Shweta	79.30	54.60	66.95	4.03	3.88	3.96	40.26	38.78	39.52
31	W-405	80.55	58.80	69.68	3.20	3.09	3.15	31.99	30.94	31.47
32	Bhima Shubra	79.25	67.05	73.15	3.52	3.52	3.52	35.16	35.20	35.18
33	Bhima Safed	73.85	54.95	64.40	4.00	3.89	3.95	40.01	38.94	39.48
34	W-310-GP	82.95	66.00	74.48	3.31	3.47	3.39	33.09	34.73	33.91
35	W-344	93.95	62.28	78.12	4.30	4.12	4.21	42.99	41.17	42.08

36	W-355	96.85	77.83	87.34	4.05	4.10	4.08	40.52	41.03	40.78
37	W-361	88.00	68.73	78.37	4.10	3.77	3.94	40.96	37.74	39.35
38	W-504	95.85	53.20	74.53	3.32	3.37	3.35	33.20	33.69	33.45
39	W-448	92.50	58.75	75.63	4.49	4.01	4.25	44.95	40.06	42.51
40	W-125-GP	58.35	69.70	64.03	3.43	3.58	3.51	34.27	35.81	35.04
41	W-210-GP	95.80	59.18	77.49	3.32	3.41	3.37	33.15	34.12	33.64
42	W-203-GP	77.75	61.95	69.85	3.67	3.76	3.72	36.69	37.60	37.15
43	W-408	86.05	65.85	75.95	4.07	3.97	4.02	40.73	39.70	40.22
44	NHRDF Furasangi	96.45	72.35	84.40	4.54	4.45	4.50	45.40	44.49	44.95
45	AFLR	83.90	64.85	74.38	4.63	4.45	4.54	46.33	44.51	45.42
46	NHRDF Red-4	103.60	73.28	88.44	4.74	4.77	4.76	47.43	47.72	47.58
47	NHRDF Red-2	113.35	66.50	89.93	5.02	5.09	5.06	50.24	50.89	50.57
48	AFDR	96.80	61.23	79.02	4.10	3.89	4.00	40.96	38.93	39.95
49	Arakera local	66.10	64.63	65.37	3.44	3.66	3.55	34.43	36.64	35.54
50	N-53	81.70	57.70	69.70	3.77	3.57	3.67	37.72	35.68	36.70
	Grand mean	**83.42**	**65.04**	**74.24**	**4.00**	**3.91**	**3.96**	**40.02**	**39.13**	**39.58**
	S.Em±	**7.76**	**5.55**	**5.73**	**0.34**	**0.28**	**0.11**	**3.38**	**2.80**	**1.06**
	CD (5%)	**22.05**	**15.76**	**16.29**	**0.96**	**0.80**	**0.30**	**9.62**	**7.95**	**3.01**

Table 5 Mean performance of onion genotypes for the rings per bulb and pre-mature bolting percentage during rabi-2023-24 and 2024-25

Sl. No.	Genotypes	Rings per bulb			Pre-mature bolting (%)			Bulb colour
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	
1	Arka Bheem	9.50	8.50	9.00	4.50	3.50	4.00	Red
2	Balichakra-W	8.50	7.50	8.00	5.00	1.00	3.00	Light red
3	Bagdal Local	8.50	8.50	8.50	4.00	2.00	3.00	Light red
4	Arka Kalyan	8.50	9.50	9.00	2.00	4.50	3.25	Red
5	Balichakra-R	7.50	8.50	8.00	2.00	1.00	1.50	Light red
6	NHRDF Red	7.50	9.50	8.50	4.50	0.00	2.25	Dark red
7	Telagi -L	7.50	7.50	7.50	1.00	1.00	1.00	Light red
8	Telagi -W	8.50	9.50	9.00	2.00	1.00	1.50	White
9	Bellary Red	9.50	8.50	9.00	1.00	1.00	1.00	Red
10	GWO-1	8.50	9.50	9.00	0.50	0.00	0.25	White
11	GJRO-11	6.50	7.50	7.00	1.00	1.00	1.00	Red
12	GJWO-3	8.00	10.00	9.00	0.00	0.00	0.00	White
13	Bhima Red	7.50	7.50	7.50	0.00	2.50	1.25	Red
14	DOGR-1770	7.50	8.50	8.00	1.00	1.50	1.25	Red
15	DOGR-1760	7.50	7.50	7.50	4.00	4.00	4.00	Light red
16	DOGR-1761	7.50	8.50	8.00	0.50	0.00	0.25	Dark red

17	DOGR-1771	8.50	7.50	8.00	1.50	1.00	1.25	Dark red
18	DOGR-1773	8.50	8.50	8.50	1.00	0.50	0.75	Light red
19	DOGR-1774	7.50	8.50	8.00	1.00	2.50	1.75	Red
20	Bhima Super	7.50	7.50	7.50	2.00	2.00	2.00	Light red
21	Bhima Raj	7.50	7.50	7.50	3.00	2.50	2.75	Dark red
22	Bhima Shakti	8.50	7.50	8.00	1.00	0.00	0.50	Light red
23	Bhima Light Red	9.50	9.50	9.50	1.00	0.00	0.50	Light red
24	DOGR-1772	6.50	7.50	7.00	1.00	0.00	0.50	Dark red
25	DOGR-1769	10.00	9.50	9.75	2.00	0.00	1.00	Light red
26	DOGR-1768	11.00	10.00	10.50	2.50	2.00	2.25	Dark red
27	Bhima Dark Red	8.50	9.50	9.00	1.00	1.00	1.00	Dark red
28	Bhima Kiran	9.00	7.50	8.25	1.00	0.00	0.50	Light red
29	W-364 GP	10.00	9.50	9.75	0.50	1.00	0.75	White
30	Bhima Shweta	9.50	10.00	9.75	1.00	0.00	0.50	White
31	W-405	6.50	9.50	8.00	1.00	1.00	1.00	White
32	Bhima Shubra	10.00	9.50	9.75	0.50	1.00	0.75	White
33	Bhima Safed	8.50	7.50	8.00	0.50	2.00	1.25	White
34	W-310-GP	8.50	8.50	8.50	0.00	0.00	0.00	White
35	W-344	10.00	9.50	9.75	0.00	0.00	0.00	White
36	W-355	9.50	9.50	9.50	2.00	0.00	1.00	White
37	W-361	10.00	9.50	9.75	2.00	0.00	1.00	White
38	W-504	8.50	9.50	9.00	1.00	0.00	0.50	White
39	W-448	12.00	11.00	11.50	0.00	1.00	0.50	White
40	W-125-GP	9.50	7.00	8.25	0.00	0.00	0.00	White
41	W-210-GP	9.50	9.50	9.50	0.00	0.00	0.00	White
42	W-203-GP	8.50	8.50	8.50	0.00	0.00	0.00	White
43	W-408	10.00	9.50	9.75	1.00	1.00	1.00	White
44	NHRDF Furasangi	8.50	8.50	8.50	2.00	1.00	1.50	Light red
45	AFLR	10.00	9.50	9.75	3.00	1.00	2.00	Light red
46	NHRDF Red-4	8.00	10.00	9.00	1.00	1.00	1.00	Light red
47	NHRDF Red-2	9.50	10.00	9.75	2.00	2.00	2.00	Light red
48	AFDR	8.50	9.50	9.00	1.00	1.00	1.00	Dark red
49	Arakera local	9.00	7.50	8.25	1.00	2.00	1.50	Light red
50	N-53	8.50	8.50	8.50	5.00	2.00	3.50	Light red
	Grand mean	**8.67**	**8.77**	**8.72**	**1.51**	**1.05**	**1.28**	
	S.Em±	**0.70**	**0.60**	**0.52**	**0.21**	**0.19**	**0.66**	
	CD (5%)	**1.98**	**1.70**	**1.48**	**0.61**	**0.53**	**1.88**	

Table 6 Mean performance of onion genotypes for the incidence of purple blotch and thrips infestations during rabi-2023-24 and 2024-25

Sl. No.	Genotypes	Purple blotch (%)			Thrips (Nymphs)		
		2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
1	Arka Bheem	2	4	3	4.47	4.45	4.46
2	Balichakra-W	2	2	2	6.01	5.98	6.00
3	Bagdal Local	2	3	2	5.04	5.02	5.03
4	Arka Kalyan	1	4	2	2.31	2.29	2.30
5	Balichakra-R	1	2	1	3.90	3.88	3.89
6	NHRDF Red	3	2	2	4.70	4.67	4.69
7	Telagi -L	2	2	2	3.68	3.65	3.67
8	Telagi -W	1	3	2	5.60	5.57	5.59
9	Bellary Red	2	2	2	1.59	1.59	1.59
10	GWO-1	1	4	2	4.35	4.34	4.35
11	GJRO-11	2	4	3	5.88	5.85	5.87
12	GJWO-3	1	4	2	4.33	4.30	4.32
13	Bhima Red	1	4	2	5.21	5.19	5.20
14	DOGR-1770	1	3	2	4.63	4.61	4.62
15	DOGR-1760	0	3	2	4.19	4.16	4.18
16	DOGR-1761	1	4	2	3.78	3.75	3.77
17	DOGR-1771	1	3	2	3.95	3.93	3.94
18	DOGR-1773	1	3	2	1.62	1.63	1.63
19	DOGR-1774	1	3	2	8.02	7.99	8.01
20	Bhima Super	1	4	3	2.09	2.08	2.09
21	Bhima Raj	1	4	2	2.07	2.07	2.07
22	Bhima Shakti	1	2	2	4.33	4.30	4.32
23	Bhima Light Red	1	1	1	1.98	1.97	1.98
24	DOGR-1772	1	3	2	1.92	1.91	1.92
25	DOGR-1769	1	1	1	8.39	8.35	8.37
26	DOGR-1768	1	2	1	11.00	10.93	10.97
27	Bhima Dark Red	0	1	1	6.42	6.40	6.41
28	Bhima Kiran	1	3	2	8.02	7.99	8.01
29	W-364 GP	0	4	2	6.28	6.26	6.27
30	Bhima Shweta	0	3	2	4.01	3.99	4.00
31	W-405	0	4	2	11.85	11.78	11.82
32	Bhima Shubra	1	2	2	1.74	1.73	1.74
33	Bhima Safed	0	3	2	7.39	7.35	7.37
34	W-310-GP	1	3	2	3.06	3.09	3.08
35	W-344	0	3	1	3.33	3.32	3.33
36	W-355	0	3	2	0.90	0.91	0.91
37	W-361	0	3	1	2.01	2.01	2.01

38	W-504	1	3	2	8.99	8.94	8.97
39	W-448	0	3	2	6.35	6.32	6.34
40	W-125-GP	1	3	2	12.35	12.29	12.32
41	W-210-GP	1	3	2	8.45	8.41	8.43
42	W-203-GP	1	4	2	8.13	8.09	8.11
43	W-408	0	2	1	5.27	5.26	5.27
44	NHRDF Furasangi	1	1	1	1.21	1.21	1.21
45	AFLR	1	1	1	7.70	7.66	7.68
46	NHRDF Red-4	1	0	1	3.35	3.35	3.35
47	NHRDF Red-2	0	0	0	4.26	4.25	4.26
48	AFDR	0	2	1	5.19	5.15	5.17
49	Arakera local	0	1	0	0.51	0.51	0.51
50	N-53	1	1	1	6.54	6.48	6.51
	Grand mean	**0.88**	**2.64**	**1.72**	**4.97**	**4.94**	**4.96**
	S.Em±	**0.26**	**0.51**	**0.58**	**0.47**	**0.44**	**0.01**
	CD (5%)	**0.73**	**1.45**	**1.66**	**1.33**	**1.25**	**0.03**

Table 7 Estimates of variability, heritability and genetic advance for different characters in onion genotypes during rabi-2023-24 and 2024-25 at Dharwad

Sl. No.	Characters	Range		Mean	GCV (%)	PCV (%)	h^2_{BS} (%)	GA	GAM (%)
		Min	Max						
1.	Plant height (cm)	39.18	56.53	49.38	8.41	9.78	74.00	7.36	14.91
2.	Number of leaves per plant	6.75	10.00	8.28	3.8192*	11.90	-10.00	-0.21	-2.53
3.	Leaf area (cm^2)	353.65	526.58	439.03	9.92	10.95	82.00	81.20	18.49
4.	Leaf area index	2.36	3.51	2.93	9.90	10.94	82.00	0.54	18.47
5.	Days to maturity(days)	89.00	99.50	94.32	1.83	3.26	31.00	2.00	2.12
6.	Pre-mature bolting (%)	39.18	55.26	46.81	3.5163*	10.60	-11.00	-1.15	-2.40
7.	Bulb polar diameter (cm)	47.78	63.26	55.64	5.44	6.84	63.00	4.97	8.93
8.	Bulb equatorial diameter (cm)	0.66	1.04	0.85	9.37	11.26	69.00	0.14	16.05
9.	Bulb neck thickness (cm)	0.56	1.14	0.88	15.28	19.38	62.00	0.22	24.81
10.	Bulb dry matter content(g)	12.63	18.28	15.29	6.56	7.76	71.00	1.75	11.42
11.	Total soluble solid (^{0}B)	10.05	15.70	12.55	3.78	9.35	16.00	0.43	3.15
12.	Average weight of bulb (g)	62.64	89.93	74.23	4.93	11.98	17.00	3.10	4.18
13.	Number of rings per bulb	7.00	11.50	8.72	10.28	10.96	88.00	1.73	19.86
14.	Bulb yield per plot (kg)	3.08	5.06	3.96	10.86	11.50	89.00	0.84	21.12

GCV- Genotypic co-efficient of variation, h^2_{BS} - Broad sense heritability, PCV- Phenotypic co-efficient of variation, GAM- Genetic advance as per cent of mean, GA- Genetic advance

Plant height ranged from 39.18 cm (W-125-GP) to 56.53 cm (GJRO-11), with a mean of 49.38 cm. Number of leaves ranged from 6.75 to 10.00 (mean 8.28). High plant height in GJRO-11 supports its vigor, as noted by Malik *et al*. (2024) for similar long-day genotypes. Leaf area varied from 353.65 to 526.58 cm^2 (mean 439.03) and LAI from 2.36 to 3.51 (mean 2.93). These traits, critical for photosynthesis, showed high variability, consistent with Saha *et al*. (2024). Maturity ranged from 89 to 99.5 days (mean 94.32) and premature bolting from 39.18% to

55.26% (mean 46.81). Low bolting in genotypes like NHRDF Red-2 aligns with Malik *et al*. (2024). Polar diameter ranged from 47.78 to 63.26 cm (mean 55.64), equatorial diameter from 0.66 to 1.04 cm (mean 0.85), neck thickness from 0.56 to 1.14 cm (mean 0.88), rings per bulb from 7 to 11.5 (mean 8.72), dry matter from 12.63 to 18.28 g (mean 15.29), TSS from 10.05 to 15.70 °Brix (mean 12.55) and bulb weight from 62.64 to 89.93 g (mean 74.23). High TSS in Bhima Shakti (15.70 °Brix) and low neck thickness in GWO-1 (0.56 cm) indicate quality and storage potential (Gupta *et al*., 2024). Bulb yield per plot ranged from 3.08 to 5.06 kg (mean 3.96 kg), translating to 30.8-50.6 t/ha. Top performers included NHRDF Red-2 (50.6 t/ha), NHRDF Red-4 (48.5 t/ha), Balichakra-R (47.2 t/ha), Bhima Raj (46.5 t/ha) and GWO-1 (45.8 t/ha), outperforming India's average productivity (16.10 t/ha) and aligning with high-yield reports by Rani *et al*. (2024). Purple blotch incidence ranged from 0% (e.g., NHRDF Red-2) to 4% (Bhima Super), with a mean of ~1.5%. Thrips incidence varied from 0.51 (Arakera local) to 12.35 (W-125-GP), mean ~4.8/plant. Low disease in NHRDF Red-2 supports its suitability, as per Choudhary *et al*. (2022).

PCV exceeded GCV for all traits (Table7), indicating environmental influence, consistent with Singh *et al*. (2022) and Amir *et al*. (2023). Bulb neck thickness (15.28%, 19.38%), bulb yield per plot (10.86%, 11.50%), leaf area (9.92%, 10.95%), LAI (9.90%, 10.94%) and number of rings per bulb (10.28%, 10.96%) showed substantial variability, suggesting strong genetic diversity for selection, as supported by Chand *et al*. (2024). Plant height (8.41%, 9.78%), bulb polar diameter (5.44%, 6.84%), equatorial diameter (9.37%, 11.26%) and dry matter content (6.56%, 7.76%) indicated moderate variability, suitable for improvement (Bal *et al*., 2022). Days to maturity (1.83%, 3.26%), TSS (3.78%, 9.35%), bulb weight (4.93%, 11.98%), leaves per plant (3.82%, 11.90%) and bolting (3.52%, 10.60%) showed limited genetic variability, likely due to environmental effects (Manjunath and Hiremath, 2022).

Bulb yield per plot (89%, 21.12%), leaf area (82%, 18.49%), LAI (82%, 18.47%) and bulb neck thickness (62%, 24.81%) indicated strong additive gene action, ideal for direct selection, as reported by Saha *et al*. (2024). Number of rings per bulb (88%, 19.86%), plant height (74%, 14.91%), dry matter (71%, 11.42%) and equatorial diameter (69%, 16.05%) showed selection potential (Prakash *et al*., 2023). Days to maturity (31%, 2.12%), TSS (16%, 3.15%) and bulb weight (17%, 4.18%) were environmentally influenced, limiting genetic gains, consistent with Komali *et al*. (2021). Number of leaves (-10%, -2.53%) and premature bolting (-11%, -2.40%) suggested statistical artifacts or strong environmental control, requiring cautious interpretation (Singh *et al*., 2022).

The high h^2BS and GAM for yield and leaf traits align with Manjunath and Hiremath (2022), indicating additive genetic control, while low values for maturity and TSS reflect environmental sensitivity (Rani *et al*., 2024). Negative heritability values may result from low genetic variance or computational issues, as noted by Singh *et al*. (2022), warranting further data validation.

High variability and heritability in bulb yield, leaf area and neck thickness suggest these traits are prime targets for selection, supporting findings by Bal *et al*. (2022). Top-performing genotypes like NHRDF Red-2 and Balichakra-R, with low disease incidence are promising for breeding, as seen in Alam *et al*. (2023) for salinity tolerance. Environmental influence on traits like TSS and maturity necessitates multi-environment testing, as emphasized by Tignegre *et al*. (2022).

IV. CONCLUSION

The study identified significant genetic variability and high-performing genotypes (e.g., NHRDF Red-2, NHRDF Red-4) for yield and quality traits. High heritability and GAM for bulb yield, leaf area andneck thickness highlight their suitability for breeding programs. Future efforts should focus on multi-location trials to confirm stability and explore hybridization for enhanced yield and adaptability.

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