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Genotypic × Environment Interaction and Stability Analysis for Bulb Yield and Yield Attributes in Onion (*Allium cepa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted for estimating the Genotypic × Environment interaction and stability for bulb yield and yield attributes in onion. 36 elite genotypes were evaluated during winter season (rabi) 2022-23 at three different environments in 3 replications. Estimate of environment wise analysis of variance suggested the significant differences for all the characters in all environments. Significant mean squares due to environments were also observed for all the traits under study

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showed that environments selected for study were random and different in agro-climatic conditions. Genotypes x interactions were significant for all the characters. Joint consideration of mean performance and stability parameters revealed that parents RO-1 and RO-59 were above average stable for bulb yield and were considered suitable for general adaptation. The crosses RO-1 × RO-59, RO-1 × Pusa Shobha, RO-1 × Pusa Madhavi, Pusa Shobha × Pusa Madhavi and Pusa Madhavi × Pusa Red were considered suitable for better environmental condition for bulb yield, while, the crosses RO-1 × Bhima Kiran, RO-59 × Pusa Madhavi, RO-59 × Pusa Red, Bhima Kiran × Bhima Shakti, Bhima Kiran × Pusa Shobha, Bhima Kiran × Pusa Madhavi and Bhima Kiran × Kashi No. 1 were considered suitable for general adaptation.

Keywords: Stable genotype; genotype x environment interaction; onion; stability.

1. INTRODUCTION

Onion (*Allium cepa* L.) is one of the important bulb crop of the family Amaryllidaceae and grown widely all over the world and consumed in various forms. It has been in cultivation for more than 4000 years ago among vegetables. Onion is the third most important crop after potato and tomato. In India, onion is cultivated throughout the country mainly in states of Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Rajasthan and Bihar occupying an area of 1914 thousand hectares with production of 31.12 million tonnes [1]. It is found in most market of the world throughout the year and can be grown under wide range of Agro-climate condition. The maximum diversity of Allium species is found in a belt from Mediterranean basin to Iran and Afghanistan. Onion is cultivated mainly as annual for bulb production and biennial for seed production. The stability of performance of genotypes over environments is of great significance to the vegetable breeders in order to separate effect of environment. Khar et al., [2] Many varieties of different crops do not show consistency in performance when grown over environments owing to the presence of genotype × environment interaction. Such interactions change relative ranking of genotypes in different environments and also reduce magnitude of genetic differences among the genotypes. This poses a problem before the vegetable breeders in proper assessment of genotypes tested under different environmental conditions. The study of genotype × environment interaction is important not only from the genetical and evolutionary point of view but also gains significance to tackle agricultural problem in general and with regards to breeding in particular [3]. Stability study is not only important in finding out the stable genotypes for varied environmental conditions but also equally useful in screening the different genotypes for their comparative performance under a particular set of environments. Besides the high productivity of genotype, the stability of its performance is also necessary for stabilizing the production. Ceccarelli (1989) expressed that higher attention should be given to the assessment of yield stability. Eberhart and Russell [4] discussed stability of genotypes in terms of three parameters – mean, regression or linear response and deviation from regression. They suggested that a stable variety is one with high mean, unit regression and least deviation from regression.

2. MATERIALS AND METHODS

The experiment was conducted at Horticulture Research Farm, Sri Karan Narendra College of Agriculture, Jobner Rajasthan to evaluate the stability of genotypes in different environmental conditions in terms of bulb yield and yield related characters. During *rabi* 2021-22 crossing block was constructed and direct F_1 crosses were produced following a half diallel mating design. The experimental material consisting of 8 parents and 28 F_1's were planted during *rabi* 2022-23. All the genotypes were sown under three different environments namely; early, normal and late environment. The experiment was laid down in randomized block design with three replications in all the environments. The plot for non-segregating generations (parents and F_1's) represented two rows each. Rows were planted in 3m length spaced at 15cm apart and 10 cm interplant distance under all the environments. Non experimental rows were planted all around the experimental material to avoid any possible border effects. Sowing was done by hand drilling of the seeds in the soil. All other agricultural practices were done according to the recommendation and package of practices implemented at optimum period to establish good crop population in the field. Observations were recorded on five randomly selected competitive plants from each replication and environment for the bulb yield attributes and quality parameters namely, plant height, number of leaves, total chlorophyll content, number of days to 50% neckfall, average bulb weight, bulb volume, number of scales, neck thickness, equatorial diameter, polar diameter, polar : equatorial ratio, bulb yield, thrips incidence, purple blotch disease incidence, total soluble solids, allyl propyl disulphide. The data on each character for the genotypes were subjected to standard statistical analysis of variance for each environment separately [5]. Later the data of each were subjected to pooled analysis of variance [6]. The statistical analysis for genotype x environment interaction and phenotypic stability was carried out according to Eberhart and Russell [4] for bulb yield and its components.

According to Eberhart and Russell [4] the mean performance of the i^{th} genotype in j^{th} environment, Y_{ij} is defined as

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

Where,

Y_{ij} = Phenotypic expression of a particular genotype (i) in specific environment (j)

Where,

I = 1, 2, ... , g genotypes
J = 1, 2, ... , e environments
μ_i = Mean of the i^{th} genotype over all environments
β_i = Regression coefficient that measures the linear response of the i^{th} genotype to varying environments
I_j = Environment index obtained as the mean of all the genotypes at the j^{th} environment minus the grand mean

3. RESULTS AND DISCUSSION

3.1 Pooled Analysis of Variance

The pooled analysis of variance showed highly significant difference among genotypes for all the characters. The environmental effects were also found highly significant for all the characters. While genotype x environment interaction were significant for most of the characters. It indicated the differential influence of environment on the expression of genotypes with respect to most of the characters including bulb yield per plant (g). Similar finding of significant G × E interaction also have been reported by Khar et al. [2] and Tahir et al. [3] in onion [Table 1].

The mean square due to environmental (E), genotype (G) × environmental (E), environmental (linear) and genotype × environmental (linear) were significant. The mean sum of squares due to pooled deviation (non linear) were significant indicating role of unpredictable causes affecting stability and prediction of these attributes would be difficult [Table 1]. Khar et al. [2] and Tahir et al. [3] in onion, Dhadukt et al. [7] Singh et al. [8] and Belay et al. [9] in garlic, Tak et al. [10] in cucumber also reported similar results.

For interpretation of results considering only bulb yield per plant, deviation from regression (unpredictable) was taken as a parameter of stability and regression coefficient as a parameter of responsiveness. The parents like RO-1 and RO-59 for average bulb weight and bulb yield, Pusa Madhavi for plant height and total chlorophyll content, Bhima Kiran, Pusa Shobha, Pusa Red for number of days to 50 % neckfall, Bhima Shakti for allyl propyl disulphide were stable but their performance was exhibiting average stability and adaptability, hence, most stable. The parents like RO-1 for total soluble solids, Kashi No. 1 for allyl propyl disulphide, Pusa Madhavi for equatorial diameter exhibiting below average stability hence, were desirable for better environment. The Parents like RO-1 for neck thickness, bulb volume, number of scales, Bhima Kiran for number of leaves exhibiting above average stability hence, these crosses were suited for poor environmental condition [Table 2]. Among the F_1s RO-1 × Bhima Kiran, RO-59 × Pusa Red, Bhima Kiran × Bhima Shakti, Bhima Kiran × Pusa Shobha, Bhima Kiran × Pusa Madhavi and Bhima Kiran × Kashi No. 1 were most stable along with high mean value, hence were considered desirable. The crosses RO-1 × RO-59, RO-1 × Pusa Shobha, Pusa Shobha × Pusa Madhavi and Pusa Madhavi × Pusa Red had regression more than unity along with high mean value, exhibiting more responsiveness hence were considered desirable for better environmental conditions only. The crosse RO-1 × Kashi No. 1 had high mean value and regression coefficient more than unity, exhibiting less responsiveness, therefore were desirable for poor environmental condition [Table 2]. Khar et al. [2] and Tahir et al. [3] in onion, Dhadukt et al. [7] Singh et al. [8] and Belay et al. [9] in garlic, Somanath [11] Soni [12] Yadav and Ram [13] Singh and Ram [14] Khan and Sarolia [15] Farag et. al. [16] Tak et al. [10] in cucurbits also reported similar results.

Since *per se* performance and stability are two independent traits and are controlled by different

Table 1. Pooled analysis of variance showing mean squares of parents and F_1's for yield and *its contributing attributes*

Particulars		Mean Squares													
Source of Variation	**df**	**Plant height (cm)**	**Number of leaves**	**Chlorophyll content of leaves (mg/100g)**	**Number of days to 50% neckfall**	**Average bulb weight (g**	**Bulb volume (cc)**	**Number of scales**	**Neck thickness (cm)**	**Equatorial diameter (cm)**	**Polar diameter (cm)**	**Polar : Equatorial ratio**	**Bulb yield (q/ha)**	**Total soluble solids (%)**	**Allyl propyl disulphide (mg/100g)**
Genotypes (G)	35	104.58**	1.34**	0.011**	35.41**	77.47**	24.84**	1.05**	0.0153**	0.13**	0.12**	0.0021**	3313.48**	0.74**	353.23**
Environment (E)	2	1353.74**	26.36**	0.074**	813.29**	4510.98**	217.4**	6.53**	0.3003**	0.51**	1.08**	0.0129**	203060.96**	0.65**	2.23
G x E	70	22.42**	0.39**	0.01**	14.04**	11.86**	11.77**	0.45**	0.0048**	0.07**	0.05**	0.0024**	528.02**	0.36**	226.23**
E + (G x E)	72	59.4**	1.11**	0.011**	36.24**	136.83**	17.48**	0.62**	0.013**	0.08**	0.08**	0.0027**	6153.9**	0.37**	255.35**
E (linear)	1	2707.5**	52.72**	0.149**	1626.57**	9021.91**	434.8**	13.06**	0.6005**	1.02**	2.17**	0.0259**	406122.09**	1.31**	209.7**
G x E (linear)	35	17.36**	0.34**	0.014**	21.2**	9.15**	9.62**	0.53**	0.0044**	0.08**	0.05**	0.0028**	412.58**	0.28**	468.48**
Pooled deviation	36	26.72**	0.43**	0.005**	6.69**	14.16**	13.53**	0.36**	0.0051**	0.06**	0.04**	0.002**	625.59**	0.43**	17.29**
Pooled Error	216	4.653	0.097	0.001	2.653	4.033	2.507	0.04	0.001	0.017	0.017	0.0005	146.51	0.07	3.91

**, **Significant at 5 percent and 1 percent levels, respectively* sets of gene system [13]. It was expected that the stability of F_1s might be influenced by sets of genes for stability present in parents. The results indicated that sets of genes for stability were inherited from its parents but this relationship was not noticed in all the cases. On the basis of these results, it can be concluded that the inheritance of stability has differential behavior for genotypes. Therefore, further study is needed to learn more about inheritance of stability.

Table 2a. Estimates of stability parameters for Bulb yield (q/ha)

Parents/ cross	Bulb yield (q/ha)		
	$\overline{X}$	bi	S^2_{di}
Parents			
RO-1 (P1)	278.51	1.01	-139.4357
RO-59 (P2)	267.47	0.99	-36.3512
BhimaKiran (P3)	230.19	1.01	-145.5624
Bhima Shakti (P4)	232.64	1.01	5.876
PusaShobha (P5)	230.93	1.01	-145.8906
PusaMadhavi (P6)	223.30	1	-102.653
Kashi No. 1 (P7)	209.51	0.92	-127.4577
Pusa Red (P8)	206.92	0.95	0.2094
Crosses			
P1xP2	344.32	1.37**	-132.8259
P1xP3	282.51	1	-118.9602
P1xP4	232.86	0.6	665.8768*
P1xP5	320.75	1.45*	215.3321
P1xP6	325.79	1.44*	180.6978
P1xP7	286.96	0.71	143.4808
P1xP8	289.33	1.07	3270.9129**
P2xP3	237.16	0.98	-144.5181
P2xP4	217.44	0.54	515.4691*
P2xP5	239.53	0.99	-127.2998
P2xP6	253.76	0.98	-144.6507
P2xP7	242.94	1.02*	-145.2297
P2xP8	259.76	0.96	-103.0539
P3xP4	258.13	0.99	-77.0878
P3xP5	268.95	0.97	-131.0191
P3xP6	276.44	1.07**	-140.23402
P3xP7	273.32	0.98**	-145.9341
P3xP8	245.09	0.96	-26.1832
P4xP5	242.49	0.98	495.8368*
P4xP6	250.64	0.93	-93.7499
P4xP7	227.60	0.76	9322.33**
P4xP8	203.95	0.99	2858.816**
P5xP6	234.93	1	-6.5113
P5xP7	215.74	0.93	1160.4988**
P5xP8	271.47	1.37	253.6648
P6xP7	222.26	1.03	314.983
P6xP8	266.50	1.19	218.8018
P7xP8	251.09	0.83**	-141.3573
General mean	253.37	1.00	
S.E. (bi)		0.15	

Table 2b. Estimates of stability parameters for Plant height (cm)

Parents/ cross	Plant height (cm)		
	$\overline{X}$	Bi	S^2_{di}
Parents			
RO-1 (P1)	62.82	0.95	-0.753

Parents/ cross	Plant height (cm)		
	$\overline{X}$	Bi	S^2_{di}
RO-59 (P2)	60.61	0.97	-3.913
BhimaKiran (P3)	63.02	0.82	0.047
Bhima Shakti (P4)	57.72	0.75	0.887
PusaShobha (P5)	62.42	-0.01**	-3.123
PusaMadhavi (P6)	67.99	0.91	-1.023
Kashi No. 1 (P7)	57.63	1.21	-0.173
Pusa Red (P8)	61.97	0.86	84.417**
Crosses			
P1xP2	73.54	1.05	1.187
P1xP3	68.62	0.7**	-4.533
P1xP4	66.14	1.15	-1.383
P1xP5	70.06	1.64	62.637**
P1xP6	72.06	2.17	148.207**
P1xP7	67.86	0.9	39.097**
P1xP8	67.37	1.17	37.257**
P2xP3	64.60	1.03	14.197*
P2xP4	74.33	1.21	8.957
P2xP5	67.07	1.39	4.597
P2xP6	73.17	1.12	-0.003
P2xP7	65.90	1.17	0.127
P2xP8	58.31	1.04**	-4.643
P3xP4	61.00	-0.19	28.377**
P3xP5	53.41	0.74	-3.023
P3xP6	59.46	1.13	-3.403
P3xP7	55.70	1.52*	-1.323
P3xP8	58.28	0.51**	-4.273
P4xP5	70.39	0.91	17.577*
P4xP6	65.72	0.59**	-4.603
P4xP7	65.20	0.7	14.087*
P4xP8	55.68	0.97	-0.713
P5xP6	67.11	0.22**	-0.143
P5xP7	54.47	1.15	48.827**
P5xP8	69.84	2.13	132.907**
P6xP7	64.73	1.17	2.697
P6xP8	75.29	1.6**	-1.043
P7xP8	68.17	0.63	186.257**
General mean	64.66	1.00	
S.E. (bi)		0.44	

Table 2c. Estimates of stability parameters for No. of leaves

Parents/ cross	No. of leaves		
	$\overline{X}$	Bi	S^2_{di}
Parents			
RO-1 (P1)	7.62	0.77	-0.027
RO-59 (P2)	7.76	1.48**	-0.096
BhimaKiran (P3)	8.13	0.61	0.663**
Bhima Shakti (P4)	6.49	1.22	-0.007
PusaShobha (P5)	7.09	1.05	-0.057
PusaMadhavi (P6)	7.87	1.17	-0.077
Kashi No. 1 (P7)	7.51	0.85	0.743**
Pusa Red (P8)	7.11	1.33*	-0.067
Crosses			

Parents/ cross	**No. of leaves**		
	$\overline{X}$	**Bi**	**S^2_{di}**
P1xP2	9.18	1.33**	-0.0969
P1xP3	8.64	1.25*	-0.077
P1xP4	7.42	0.95	0.053
P1xP5	8.84	0.85	0.003
P1xP6	8.18	1.48	1.443**
P1xP7	8.92	0.97	0.253
P1xP8	8.26	0.47	1.023**
P2xP3	7.36	1.04	2.923**
P2xP4	8.07	1.1	0.813**
P2xP5	9.71	1.23	0.333*
P2xP6	8.00	0.93	-0.047
P2xP7	7.36	1.25**	-0.087
P2xP8	8.42	1.7	0.263
P3xP4	7.91	0.26	0.383*
P3xP5	7.20	1.46	0.163
P3xP6	8.16	0.83	0.463*
P3xP7	7.11	0.9	0.843**
P3xP8	7.27	0.56	0.123
P4xP5	7.76	1.14	-0.007
P4xP6	7.18	0.56	0.173
P4xP7	8.49	0.29	0.163
P4xP8	7.76	0.92	0.083
P5xP6	8.58	1.1	0.013
P5xP7	7.71	0.43	1.703**
P5xP8	8.09	1.55*	-0.017
P6xP7	8.02	0.56	0.073
P6xP8	8.16	2.54**	-0.047
P7xP8	8.36	-0.13**	0.103
General mean	7.94	1.00	
S.E. (bi)		0.44	

Table 2d. Estimates of stability parameters for Equatorial diameter (cm)

Parents/ cross	**Equatorial diameter (cm)**		
	$\overline{X}$	**Bi**	**S^2_{di}**
Parents			
RO-1 (P1)	4.85	1.28	-0.007
RO-59 (P2)	5.15	0.38	-0.007
BhimaKiran (P3)	5.17	1.01	-0.007
Bhima Shakti (P4)	4.93	-0.54*	-0.004
PusaShobha (P5)	5.17	0.55	0.103**
PusaMadhavi (P6)	5.43	1.41	-0.019
Kashi No. 1 (P7)	5.24	0.04	0.023
Pusa Red (P8)	5.11	0.76	0.003
Crosses			
P1xP2	5.66	0.65	-0.0143
P1xP3	5.05	1.03	0.043
P1xP4	4.97	-0.29	0.033
P1xP5	5.66	0.84	0.113**
P1xP6	5.62	1.04	0.153**
P1xP7	5.40	-2.55**	-0.007
P1xP8	5.56	2.94	0.023
P2xP3	5.36	-0.2	0.013

Parents/ cross	Equatorial diameter (cm)		
	$\overline{X}$	Bi	S^2_{di}
P2xP4	5.01	-0.04**	-0.0148
P2xP5	5.30	-1.89*	0.043
P2xP6	5.10	2.39	0.003
P2xP7	5.11	2.16	-0.007
P2xP8	5.39	2.23	0.003
P3xP4	5.31	1.6	0.073*
P3xP5	5.33	0.24	0.013
P3xP6	5.31	2.07**	-0.014
P3xP7	5.21	2.26	0.253**
P3xP8	5.11	1.28	0.113**
P4xP5	5.32	3.28**	-0.007
P4xP6	5.14	2.35	0.033
P4xP7	5.21	1.96	0.003
P4xP8	5.25	0.63	0.023
P5xP6	5.25	0.4	0.003
P5xP7	5.45	-0.13	0.015
P5xP8	5.62	4.63**	0.003
P6xP7	5.13	0.31	-0.007
P6xP8	5.38	4.77	0.543**
P7xP8	5.37	-3.56**	-0.007
General mean	5.27	0.98	
S.E. (bi)		1.17	

Table 2e. Estimates of stability parameters for Total soluble solids

Parents/ cross	Total soluble solids		
	$\overline{X}$	Bi	S^2_{di}
Parents			
RO-1 (P1)	13.04	1.79	-0.0685
RO-59 (P2)	12.32	3.83**	-0.0538
BhimaKiran (P3)	12.40	3.95**	-0.088
Bhima Shakti (P4)	12.18	2.3	0.1736
PusaShobha (P5)	11.84	3.15	0.6503**
PusaMadhavi (P6)	12.58	2.64	-0.0333
Kashi No. 1 (P7)	11.91	3.41	1.3067**
Pusa Red (P8)	11.94	-1.35	0.5**
Crosses			
P1xP2	14.17	1.6	-0.0568
P1xP3	12.69	-0.18	-0.0615
P1xP4	12.08	1.51	-0.0411
P1xP5	14.07	2.8	-0.0182
P1xP6	13.59	5.22	0.2988*
P1xP7	13.19	-6.93**	0.1038
P1xP8	13.10	-0.78	0.5745**
P2xP3	12.29	-0.6*	-0.05556
P2xP4	12.59	1.62	-0.0825
P2xP5	12.49	-2.6	0.1251
P2xP6	12.70	-1.79	1.5134**
P2xP7	12.64	1.3	-0.0817
P2xP8	12.77	6.37	0.505**
P3xP4	12.91	1.35	0.9313**
P3xP5	12.83	0.32	0.0265
P3xP6	12.67	2.66	0.05298

Parents/ cross	Total soluble solids		
	$\overline{X}$	Bi	S^2_{di}
P3xP7	12.52	-0.29	0.8811**
P3xP8	12.56	-0.23**	-0.0712
P4xP5	12.73	3.53	0.0635
P4xP6	12.96	1.27	0.1789
P4xP7	12.68	-1.51	0.0281
P4xP8	12.77	-3.21	0.5521**
P5xP6	12.42	2.91	0.5497**
P5xP7	12.50	-5.5**	-0.0467
P5xP8	12.66	3.75	0.1568
P6xP7	12.59	1.06	2.5966**
P6xP8	12.74	1.99	0.4203*
P7xP8	12.74	1.92	1.2204**
General mean	12.69	1.03	
S.E. (bi)		2.75	

Table 2f. Estimates of stability parameters for Allyl propyl disulphide

Parents/ cross	Allyl propyl disulphide		
	$\overline{X}$	Bi	S^2_{di}
Parents			
RO-1 (P1)	35.38	0.98	-0.9999
RO-59 (P2)	34.61	1.66*	-0.8157
BhimaKiran (P3)	36.66	1.85**	-1.2639
Bhima Shakti (P4)	42.88	0.94	0.8735
PusaShobha (P5)	37.64	-0.13**	-1.1838
PusaMadhavi (P6)	48.64	-1.24**	2.0008
Kashi No. 1 (P7)	45.12	1.63**	-1.2441
Pusa Red (P8)	35.05	-0.43	2.321
Crosses			
P1xP2	39.79	1.74*	-0.6002
P1xP3	38.91	2.91**	0.884
P1xP4	41.66	1.44	-0.7666
P1xP5	42.33	0.62	0.8739
P1xP6	50.69	1.87	2.2155
P1xP7	43.69	0.92	3.5525
P1xP8	40.25	1.14	-0.1383
P2xP3	37.09	0.29	32.65895**
P2xP4	43.93	1.61**	-1.1408
P2xP5	40.09	0.66	1.4512
P2xP6	41.64	2.49**	-1.1417
P2xP7	39.95	0.82*	-1.2707
P2xP8	40.04	0.46**	-1.09
P3xP4	46.77	1.48	-0.7472
P3xP5	41.37	0.31**	-1.1574
P3xP6	48.73	-0.99	7.37682*
P3xP7	46.22	1.14	1.9977
P3xP8	40.18	0.51**	-1.2756
P4xP5	37.08	2.67**	-0.4195
P4xP6	49.12	2.33**	-0.7209
P4xP7	33.57	1.84	0.1855
P4xP8	36.20	2.06	1.0184
P5xP6	48.45	-2.92**	1.2549
P5xP7	47.28	2.38*	1.3317

Parents/ cross	Allyl propyl disulphide		
	$\overline{X}$	Bi	S^2_{di}
P5xP8	41.93	0.69**	-1.239
P6xP7	33.24	1	-0.7475
P6xP8	49.12	0.43*	-0.7695
P7xP8	47.62	0.86	3.2296
General mean	41.75	1.00	
S.E. (bi)		0.47	

4. CONCLUSION

On the basis of phenotypic stability, parents viz. RO-1 and RO-59 were above average stable for bulb yield and were considered suitable for general adaptation. The crosses RO-1 X RO-59, RO-1 X Pusa Shobha, RO-1 X Pusa Madhavi, Pusa Shobha X Pusa Madhavi and Pusa Madhavi X Pusa Red were considered suitable for better environmental condition for bulb yield, while, the crosses RO-1 X Bhima Kiran, RO-59 X Pusa Madhavi, RO-59 X Pusa Red, Bhima Kiran X Bhima Shakti, Bhima Kiran X Pusa Shobha, Bhima Kiran X Pusa Madhavi and Bhima Kiran X Kashi No. 1 were considered suitable for general adaptation and the cross RO-1 X Kashi No. 1 was considered suitable for poor environmental condition in the favour of bulb yield (q/ha). To elevate the productivity level of onion crop, genetic information regarding bulb yield and various yield components will play a significant role in the selection of desirable parents and suitable breeding methods for resulting progenies to develop and execute effective breeding programme to evolve high yielding and early maturing varieties.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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