

RESEARCH ARTICLE

GENETIC VARIABILITY FOR SEED AND SEEDLING VIGOUR TRAITS IN
LENTIL (*LENS CULINARIS* MEDIKUS) GENOTYPES

Mudang Pullo and H.P. Chaturvedi*

Department of Genetics and Plant Breeding, School of Agricultural Sciences, Nagaland University,
Medziphema- 797106

Email: hpchaturvedi68@gmail.com

Received-06.07.2023, Revised-17.07.2023, Accepted-27.07.2023

Abstract: The present study encompassed 22 lentil genotypes, examining seed and seedling vigor traits during Kharif-2021 employing a completely randomized design (CRD) with three replications at the laboratory of Department of Genetics and Plant Breeding, School of Agricultural Sciences, Nagaland University. ANOVA highlighted significant variability in lentil genotypes for seed and seedling vigor traits at 1% and 5% probabilities. Analyzing these genotypes across eleven vigor-related traits revealed characteristic diversity, emphasizing genetic heterogeneity and substantial variability. Coefficient of Variation (C.V.) indicated dispersion, notably in root length (102.41%) and seedling vigor index II (78.21%). Standard Error (S.E.) signaled precision, while Critical Difference (C.D.) facilitated trait differentiation. Genotypic and phenotypic variances were highest for fresh shoot weight ($\sigma^2g = 1937.37$, $\sigma^2p = 6711.47$), followed by fresh root weight ($\sigma^2g = 332.54$, $\sigma^2p = 654.11$), and shoot length at 20th day ($\sigma^2g = 193.93$, $\sigma^2p = 465.05$). Seedling vigor index I ($\sigma^2g = 182.97$, $\sigma^2p = 579.91$), germination percentage ($\sigma^2g = 100.79$, $\sigma^2p = 399.35$), and others also exhibited notable variance. This study unveiled diverse PCV and GCV values across traits. PCV ranged from 13.12% to 109.27%, with root length at 20th day exhibiting the highest (109.27%). GCV ranged from 8.34% to 65.41%, with fresh root weight displaying the highest GCV (65.41%). Heritability ranged from 11.32% to 50.84%, with traits showing moderate heritability and substantial genetic advance including shoot length, fresh root weight, and seedling vigor indices. Traits with low heritability and high genetic advance comprised germination percentage and shoot weight.

Keywords: Lentil, Genetic variability, Heritability, Genetic advance, Correlation

INTRODUCTION

Lentil (*Lens culinaris* Medikus) is a small, lens-shaped legume that holds a significant place in human history and diets. Its phylogenetic history traces back to the Fabaceae family, commonly known as the legume or pea family. Lentils have been cultivated for thousands of years, with their origins likely in the Near East, including regions like Turkey, Syria, and Iran. These regions served as the primary centers of diversity and initial cultivation for lentils. The chromosome number of lentils, like most plants, can vary within the species. Generally, lentils have a diploid chromosome number of $2n = 14$. This genetic characteristic influences the plant's growth, development, and reproduction. Lentils have evolved through centuries of cultivation and selection, resulting in various cultivated varieties that vary in size, color, and culinary uses. They thrive in diverse climates and soil conditions, making them a valuable crop for both subsistence and commercial farming. Lentils' adaptability and nutritional profile have contributed to their continued popularity as a staple food source in many cultures (Laskar *et al.* 2019).

Lentil plays a pivotal role in global agriculture and nutrition, with around 5.8 million hectares dedicated to their cultivation worldwide, yielding approximately 6.7 million metric tons annually. Leading producers such as Canada, India, Turkey, and Australia contribute significantly to the lentil market. Notably, Canada provides 30% of the global output. In India, lentil cultivation spans 2 million hectares, yielding 1.7 million metric tons, with major states including Madhya Pradesh, Uttar Pradesh, and Rajasthan. Lentils hold immense dietary importance, especially in vegetarian diets, addressing protein deficiency. Government initiatives support Indian lentil farmers through minimum support prices, subsidies, and export facilitation (Singh *et al.* 2020). The North East India region cultivates lentils on about 100,000 hectares, contributing around 90,000 metric tons annually to local food security and dietary diversity (Sah, *et al.* 2020). Agricultural research, credit accessibility, and market linkages are championed by the government to bolster lentil production in this region. Collectively, lentils embody a crucial crop, impacting global nutrition and economies while ensuring sustainable food systems in various regions.

*Corresponding Author

Lentil research in North East India holds significant importance due to the region's unique agro-climatic conditions and its potential impact on marketing and agricultural sustainability. Lentil research in North East India plays a pivotal role in shaping lentil grain quality and subsequently impacting market success. Through fine-tuning cultivation practices to deliver superior lentil quality, research contributes to capturing consumer preferences and establishing the region as a key player in the competitive lentil market (Das et al. 2016).

Lentil research is vital in North East India due to its diverse climatic conditions. Tailoring lentil cultivation to these conditions can improve yield, ensuring food security and farmer income. Developing adapted lentil varieties enhances local sustainability and nutritional content. Research fosters eco-friendly practices, diversifies incomes, and increases market competitiveness. By empowering farmers with knowledge and innovation, lentil research will contribute to improved livelihoods and regional growth.

Genetic variability analysis in lentil (*Lens culinaris*) is crucial for breeding programs. Genetic Coefficient of Variation (GCV) quantifies inherent variability, while Phenotypic Coefficient of Variation (PCV) factors in environmental influences. Heritability estimates the genetic contribution to traits, guiding selection. Genetic Advance indicates the extent of improvement achievable through selection. Studying these parameters aids breeders in identifying traits with high heritability and GCV, ensuring efficient selection for improved lentil varieties (Gleridou et al. 2022).

Conducting research on the genetic variability for seed and seedling vigour traits in lentil (*Lens culinaris* Medikus) genotypes is essential to unlock the potential of this valuable legume crop. By addressing the existing research gap in understanding the genetic factors influencing early growth, this study aims to uncover key insights into the heritability and diversity of vigour traits. The expected outcomes hold immense promise, potentially leading to the development of lentil varieties with superior crop establishment, resilience, and yield. This research could significantly contribute to the advancement of lentil breeding programs, enabling the cultivation of more robust and productive lentil crops, thereby enhancing food security and agricultural sustainability.

MATERIALS AND METHODS

The study was conducted at laboratory of the Department of Genetics and Plant Breeding in School of Agricultural Sciences, Nagaland University, Medziphema Campus, during 2021. The location holds a sub-tropical climate and is positioned at 23° 24'49" N latitude and 90°33'04" S longitude, situated at an altitude of 305 meters above

sea level. Employing a Completely Randomized Design with three replications, the experiment incorporated twenty-two lentil genotypes (Table 1.) sourced from AICRP Pigeon pea, SAS, Medziphema, Nagaland. The investigation encompassed the observation of eleven traits including radicle emergence, plumule emergence, germination percentage, shoot and root length at the 20th day after sowing (DAS), fresh shoot and root weight at the 20th DAS, dry shoot and root weight at the 20th DAS, seedling vigour index I, and seedling vigour index II. The analysis of variance followed the approach outlined by Panse and Sukhatme (1957) using the mean performance of the genotypes. Additionally, phenotypic, genotypic, and environmental coefficient of variation were calculated based on Burton and De Vane's methodology (1953). Heritability was estimated following Allard's formula (1960), and the potential genetic advance attainable through selection was determined as per Johnson et al.'s procedure (1955). Furthermore, the phenotypic and genotypic correlation coefficients were computed, following the guidance of Al Jibouri et al. (1958).

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) reveals significant variability among the evaluated seed and seedling vigour traits within the twenty-two lentil genotypes (Table 2). The treatment factor contributes significantly to the observed variation in the emergence of radicle, emergence of plumule, germination percentage, shoot length at the 20th day, root length at the 20th day, fresh shoot weight, fresh root weight, dry shoot weight, dry root weight, seedling vigour index I, and seedling vigour index II. This indicates that the diverse genotypes respond differently to the treatment conditions, leading to substantial differences in these traits. The Mean Sum of Squares highlights the significance of these differences, with probabilities of 1% and 5% (***) indicating strong evidence of treatment effect. Comparable findings were presented in studies by Priya et al. (2021) focusing on root traits in lentil, Idrissi et al. (2015) exploring genetic variability in lentil's root and shoot traits, and Sarker et al. (2005) investigating associations between shoot and root characteristics and drought tolerance in lentil landraces.

The considerable variation observed among the genotypes underscores the rich genetic diversity present in lentil populations. This genetic diversity is likely influenced by various factors, including the genotypes' origins, adaptive traits, and inherent genetic makeup. The substantial differences in traits such as germination percentage, shoot and root length, as well as fresh and dry weights, suggest potential opportunities for selecting genotypes that exhibit superior early growth and vigour

characteristics. These findings emphasize the genetic potential to improve lentil performance during critical early growth stages through selective breeding.

The mean performance analysis of the twenty-two lentil genotypes (Table 3.) across eleven vigour-related traits reveals a diverse range of characteristics. Notable variations are observed in the grand means of emergence of radicle (3.54 days), emergence of plumule (7.86 days), germination percentage (44.54%), shoot length at the 20th day (47.59 mm), root length at the 20th day (7.94 mm), fresh shoot weight (115.31 mg), fresh root weight (27.88 mg), dry shoot weight (18.33 mg), dry root weight (11.97 mg), seedling vigour index I (270.96), and seedling vigour index II (8.43). These variations highlight the genetic heterogeneity present within the lentil genotypes, implying different genetic compositions that influence these traits. The grand mean values provide an overview of the average performance, with the coefficient of variation indicating substantial variability across traits. Corresponding studies were conducted by Crippa *et al.* (2009), Kumar *et al.* (2013), and Sarker *et al.* (2005), yielding similar results.

The coefficient of variation (C.V.) values reflect the extent of dispersion within the data, with traits such as root length at the 20th day (102.41%) and seedling vigour index II (78.21%) demonstrating higher variability. The standard error (S.E.) values suggest the precision of the estimates, aiding in interpreting the reliability of the calculated means. Furthermore, the critical difference (C.D.) values at 1% and 5% significance levels highlight the minimum significant differences between means, helping to distinguish traits with substantial variations from those with less pronounced differences.

This extensive variation in seed and seedling vigour traits among lentil genotypes presents a valuable resource for breeding programs aiming to improve early growth and overall crop performance. Traits displaying notable variation could be targeted for selection and further breeding efforts to develop lentil cultivars with enhanced vigour, resilience, and yield potential. The observed genetic diversity emphasizes the potential to harness these variations to adapt lentil crops to varying agro-climatic conditions and contribute to agricultural sustainability.

Genotypic, phenotypic, and environmental variances are classified as low (<10), medium (10-20), or high (>20) to assess trait variability intensity (Johnson *et al.* 1955). All the genetic parameters represented at (Table 4.) The analysis of variance components, including genotypic, phenotypic, and environmental variance, provides insights into the variation present among the lentil genotypes for the 11 assessed characters. Among these characters, the highest values of genotypic variance (σ^2g) and phenotypic variance (σ^2p) were observed for fresh shoot weight

($\sigma^2g = 1937.37$, $\sigma^2p = 6711.47$) followed by the characters fresh root weight ($\sigma^2g = 332.54$, $\sigma^2p = 654.11$), shoot length at 20th day ($\sigma^2g = 193.93$, $\sigma^2p = 465.05$), seedling vigour index I ($\sigma^2g = 182.97$, $\sigma^2p = 579.91$), germination percentage ($\sigma^2g = 100.79$, $\sigma^2p = 399.35$), dry shoot weight ($\sigma^2g = 19.19$, $\sigma^2p = 113.21$), root length at 20th day ($\sigma^2g = 9.32$, $\sigma^2p = 75.27$), dry root weight ($\sigma^2g = 7.21$, $\sigma^2p = 22.58$), emergence of plumule ($\sigma^2g = 3.61$, $\sigma^2p = 4.87$), emergence of radicle ($\sigma^2g = 3.22$, $\sigma^2p = 5.19$) and seedling vigour index II ($\sigma^2g = 0.46$, $\sigma^2p = 1.02$).

Environmental variance was observed maximum for the character fresh shoot weight ($\sigma^2e = 4774.11$) and followed by the characters *viz.*, seedling vigour index I ($\sigma^2e = 396.94$), fresh root weight ($\sigma^2e = 321.57$), germination percentage ($\sigma^2e = 298.56$), shoot length at 20th day ($\sigma^2e = 271.11$), dry shoot weight ($\sigma^2e = 94.01$), root length at 20th day ($\sigma^2e = 65.94$), dry root weight ($\sigma^2e = 15.37$), emergence of radicle ($\sigma^2e = 1.97$), emergence of plumule ($\sigma^2e = 1.26$) and seedling vigour index II ($\sigma^2e = 0.61$).

The substantial genotypic and phenotypic variances underscore the potential for lentil breeding programs to capitalize on these variations for trait improvement. Focusing on traits with high genotypic variance can facilitate the selection of superior genotypes, leading to enhanced crop performance. The understanding of environmental variance aids in designing experiments and management practices that mitigate external influences, contributing to accurate assessments of genetic potential. Overall, this variance analysis offers valuable guidance for lentil breeding endeavors, helping breeders make informed decisions and develop cultivars with improved vigour and overall performance.

Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) are vital statistical tools used in genetic studies to quantify the extent of variation in phenotypic and genotypic traits, respectively. These coefficients aid in assessing the level of genetic diversity present within a population and contribute valuable insights to selective breeding programs.

The investigation revealed a comprehensive range of values for PCV and GCV across the evaluated traits. The PCV values ranged from 13.12% to 109.27%, indicating significant variation in trait expression. Notably, root length at the 20th day exhibited the highest PCV (109.27%), followed by seedling vigour index I (94.51%), fresh root weight (91.74%), seedling vigour index II (78.12%), fresh shoot weight (71.05%), dry shoot weight (58.03%), germination percentage (49.39%), shoot length at the 20th day (45.31%), dry root weight (39.71%), and emergence of radicle (25.08%). Emergence of plumule displayed moderate PCV (13.15%).

On the other hand, GCV values ranged from 8.34% to 65.41%, reflecting genetic variability. Fresh root weight recorded the highest GCV (65.41%), trailed by seedling vigour index I (53.08%), seedling vigour

index II (49.27%), root length at the 20th day (38.47%), fresh shoot weight (38.17%), shoot length at the 20th day (29.26%), germination percentage (24.82%), dry shoot weight (23.89%), and dry root weight (22.44%). However, emergence of radicle (8.43%) and emergence of plumule (8.34%) displayed low GCV values.

The elevated PCV and GCV values highlight substantial genetic variation within the lentil genotypes for the assessed traits. Traits with high PCV and GCV values, such as root length at the 20th day, fresh root weight, and seedling vigour indices, offer considerable scope for selective breeding aimed at enhancing these characteristics. The comprehensive analysis of PCV and GCV underscores the genetic diversity present within the lentil population. Traits with high PCV and GCV values represent strong candidates for selection and improvement efforts. In contrast, traits with low GCV values, like emergence of radicle and emergence of plumule, may be less amenable to genetic manipulation. These coefficients provide valuable guidance for lentil breeding strategies, allowing breeders to focus on traits with the greatest potential for enhancement and contributing to the overall progress of lentil cultivation.

Heritability, a fundamental concept in genetics, quantifies the proportion of phenotypic variation attributed to genetic factors within a population. It serves as a critical parameter in assessing the potential for selective breeding to enhance desired traits. Heritability values provide insights into the degree to which genetic variation influences trait expression, guiding breeding strategies for crop improvement. Low heritability (<30%) suggests environmental impact, moderate (30-60%) balances genetics and environment, while high (>60%) emphasizes genetics' role (Johnson *et al.*, 1955).

In the current study, a broad range of heritability values was observed, spanning from 11.32% to 50.84%. Traits exhibiting moderate heritability alongside significant genetic advance included shoot length at the 20th day (41.7% and 38.93%), fresh root weight (50.84% and 96.07%), dry root weight (31.95% and 26.13%), SVI I (31.55% and 61.43%), and SVI II (39.78% and 64.02%). Moderate heritability accompanied by moderate genetic advance was evident in the emergence of plumule (40.35% and 10.91%), implying non-additive gene action.

Traits with low heritability and high genetic advance encompassed germination percentage (25.24% and 25.68%), root length at the 20th day (12.39% and 27.89%), fresh shoot weight (28.87% and 42.25%), and dry shoot weight (16.95% and 20.26%). Conversely, emergence of radicle exhibited low heritability and low genetic advance (11.32% and 5.84%).

Moderate heritability values coupled with substantial genetic advance indicate the potential for selective breeding to significantly enhance these traits. Traits with low heritability and high genetic advance may necessitate the consideration of non-genetic factors or interactions for trait improvement. Traits with low values for both heritability and genetic advance might be influenced primarily by environmental conditions, suggesting challenges in genetic manipulation.

The range of heritability values obtained in this study reflects the genetic underpinnings of trait variability within the lentil population. Traits with moderate to high heritability and substantial genetic advance present promising candidates for focused breeding efforts. The interplay between heritability and genetic advance provides valuable guidance for the development of effective selection strategies and the identification of traits that offer potential for successful enhancement through breeding programs. Kumawat and Gothwal (2018) studied Lentil's ten genotypes, observing highest variability in plumule-radicle length ratio and radicle length. Manjeet *et al.* (2019) found higher PCV than GCV in 24 sesame genotypes, particularly in seedling vigour index-I and root length.

In a sound breeding program, the study of associations between yield and its dependent characters is of particular interest and importance. Correlation coefficient analysis measures the mutual relationship between different characters and helps determine the component characters on which selection can be done for yield improvement (Sumathi & Muralidharan, 2010). Interrelationships between characters are important for the utilization of various quantitative traits in a breeding program (Lerner, 1958). Therefore, in the present study, correlations between 11 characters were studied at the genotypic and phenotypic levels (Table-5 and 6). The positive and significant correlation of seedling vigour index I & II with the majority of the traits indicated that all of the seedling traits were essential in determining seedling vigour.

Table 1. List of genotypes

List of genotypes					
Sl. No.	Treatment No.	Genotypes	Sl. No.	Treatment No.	Genotypes
1	T1	LSS 19 – 23	12	T12	LSS 19 – 14
2	T2	LSS 19 – 17	13	T13	LSS 19 – 6
3	T3	LSS 19 – 27	14	T14	LSS 19 – 16
4	T4	LSS 19 – 21	15	T15	LSS 19 – 19

5	T5	LSS 19 – 13	16	T16	LSS 19 – 18
6	T6	LSS 19 – 10	17	T17	LSS 19 – 12
7	T7	LSS 19 – 11	18	T18	LSS 19 – 9
8	T8	LSS 19 – 24	19	T19	LSS 19 – 7
9	T9	LSS 19 – 15	20	T20	LSS 19 – 22
10	T10	LSS 19 – 26	21	T21	LSS 19 – 8
11	T11	LSS 19 – 25	22	T22	LSS 19 – 20

Table 2. Analysis of variation for 11 characters in twenty two genotypes of lentil

Sources of variation	D F	Mean sum of square										
		Emergence of radicle	Emergence of plumule	Germination %	Shoot length at 20 th day (mm)	Root length at 20 th day (mm)	Fresh shoot weight (mg)	Fresh root weight (mg)	Dry shoot weight (mg)	Dry root weight (mg)	SVI I	SVI II
Treatment	21	0.96	1.92*	600.93**	852.92**	93.92	11294.37*	1291.26**	144.08	37.01**	94588**	1.82**
Error	44	0.701	0.63	298.55	271.11	65.94	5808.87	341.05	105.77	15.36	39694	0.611

Table 3. Mean performance of 22 genotypes for 11 characters in lentil

Genotypes	Emergence of radicle (days)	Emergence of plumule (days)	Germination %	Shoot length at 20 th day (in mm)	Root length at 20 th day (in mm)	Fresh shoot weight (in mg)	Fresh root weight (in mg)	Dry shoot weight (in mg)	Dry root weight (in mg)	Seedling vigour index I	Seedling vigour index II
LSS 19-23	3.66	9	53.33	44.66	11.33	116.66	30.00	13.33	13.33	298.11	7.78
LSS 19-17	3	8.33	46.66	42.33	5.66	86.66	13.33	16.66	10.00	223.50	4.62
LSS 19-27	3	7.66	53.33	31.66	7.66	116.66	13.33	13.33	10.00	209.58	6.87
LSS 19-21	3.66	7.66	26.66	34.00	8.66	40.00	16.66	10.00	10.00	113.57	1.49
LSS 19-13	3	7	53.33	49.66	10.33	143.33	20.00	20.00	10.00	319.44	8.69
LSS 19-10	3	9	33.33	43.33	8.00	70.00	16.66	13.33	10.00	170.98	28.66
LSS 19-11	3	7	80	69.44	4.66	150.00	20.00	16.66	13.33	592.8	13.6
LSS 19-24	4.33	9	46.66	72.33	9.11	173.33	16.66	30.00	10.00	379.81	8.81
LSS 19-15	3	7.66	73.33	85.33	31.00	273.33	23.33	36.66	10.00	852.83	21.7
LSS 19-26	4.33	8.33	33.33	64.00	6.33	106.66	23.33	20.00	10.00	234.31	4.29
LSS 19-25	3.66	7	30	16.66	4.10	46.66	26.66	10.00	10.00	62.28	2.19
LSS 19-14	4.33	7	96.66	66.00	6.33	220.00	36.66	30.00	16.66	698.85	24.74
LSS 19-6	3.66	8.33	50	25.33	5.66	110.00	26.66	16.66	10.00	154.95	6.8
LSS 19-16	3	9	30	39.33	4.33	143.33	43.33	20.00	16.66	130.8	5.58
LSS 19-19	3	7	50	59.41	5.33	120.00	20.00	16.66	10.00	323.5	7
LSS 19-18	4.33	7.66	36.66	41.33	7.33	60.00	13.33	13.33	10.00	178.16	2.67
LSS 19-12	3.66	7.66	13.33	34.33	4.00	40.00	13.33	10.00	10.00	51.05	0.71
LSS 19-9	3	7	36.66	43.66	6.66	100.00	26.66	13.33	10.00	184.47	4.62
LSS 19-7	3	7.66	26.66	43.00	9.00	130.00	76.66	20.00	16.66	138.63	5.49
LSS 19-22	4.33	7.66	56.66	55.66	10.00	120.00	96.66	26.66	23.33	371.68	12.24
LSS 19-8	4.33	9	20	29.66	5.33	23.33	13.33	10.00	10.00	69.8	0.72
LSS 19-20	3	8.33	33.33	56.66	4.00	146.66	36.66	20.00	10.00	202.17	6.09
Grand mean	3.54	7.86	44.54	47.59	7.94	115.31	27.88	18.33	11.97	270.96	8.43
C.V	23.65	10.14	42.72	34.61	102.41	59.91	64.32	52.91	32.79	78.21	60.62
S.E	0.48 NS	0.46	9.97	9.51	4.69	39.89	10.35	5.61	2.26	115.03	0.45
C.D. 1%	1.85 NS	1.75	38.06 NS	36.27	17.88 NS	152.21 NS	39.51	21.36 NS	8.63	438.91	1.72
C.D. 5%	1.38	1.31	28.47	27.13	13.40 NS	113.85	29.54	15.97 NS	6.46	328.28	1.28

Table 4. Genetic parameters of variance and others related genetic parameters for 11 characters of lentil genotypes

Sl. No.	Characters	Range	Mean	Variance			GCV	PCV	ECV	h ² (broad sense)	G.A	GA as % of mean
				σ^2_e	σ^2_g	σ^2_p						
1	Emergence of radicle	3-5	3.54	0.71	0.09	0.79	8.43	25.08	23.62	11.32	0.21	5.84
2	Emergence of plumule	6-9	7.86	0.63	0.43	1.06	8.34	13.12	10.14	40.35	0.86	10.91
3	Germination %	13.33-96.66	44.54	298.56	100.79	399.35	24.82	49.39	42.72	25.24	10.39	25.68

4	Shoot length at 20th day	16.66-85.33	47.59	271.11	193.93	465.05	29.26	45.31	34.61	41.7	18.52	38.93
5	Root length at 20th day	4.00-31.00	7.94	65.94	9.32	75.27	38.47	109.27	102.27	12.39	2.22	27.89
6	Fresh shoot weight (mg)	23.33-273.33	115.303	4774.11	1937.37	6711.47	38.17	71.05	59.92	28.87	48.72	42.25
7	Fresh root weight (mg)	13.33-96.66	27.88	321.57	332.54	654.11	65.41	91.74	64.33	50.84	26.78	96.07
8	Dry shoot weight (mg)	10-36.66	18.33	94.01	19.19	113.21	23.89	58.03	52.88	16.95	3.72	20.26
9	Dry root weight (mg)	10-23.33	11.97	15.37	7.21	22.58	22.44	39.71	32.75	31.95	3.13	26.13
10	SVI I	51.05-852.82	270.96	396.94	182.97	579.91	53.08	94.51	78.19	31.55	15.65	61.43
11	SVI II	0.71-28.66	8.43	0.61	0.46	1.02	49.27	78.12	60.62	39.78	0.82	64.02

Table 5. Genotypic correlation coefficient matrix (rg) for 11 characters in lentil

Characters	Emergence of radicle	Emergence of plumule	Germination %	Shoot length at 20 th day	Root length at 20 th day	Fresh shoot weight	Fresh root weight	Dry shoot weight	Dry root weight	SVI I	SVI II
Emergence of radicle	-	0.44*	-0.37 NS	-0.05 NS	-0.49*	-0.59**	0.27 NS	0.08 NS	0.57**	-0.16 NS	-0.009 NS
Emergence of plumule		-	-0.24 NS	0.02 NS	-0.27 NS	-0.18 NS	0.06 NS	0.02 NS	0.06 NS	-0.124 NS	-0.07 NS
Germination %			-	0.91**	1.56**	0.35**	0.005 NS	1.48**	0.36 NS	1.07**	0.94**
Shoot length at 20 th day				-	0.66**	0.86**	0.01 NS	1.07**	0.19 NS	0.84**	0.8**
Root length at 20th day					-	1.09**	-0.12 NS	1.6**	0.01 NS	1.23**	1.55**
Fresh shoot weight						-	0.27 NS	1**	0.46**	1.21**	1.04**
Fresh root weight							-	0.66**	0.93**	-0.02 NS	0.37 NS
Dry shoot weight								-	0.85**	1.51**	1.25**
Dry root weight									-	0.14 NS	0.6**
SVI I										-	1.07**
SVI II											-

* and** significant at 5% and 1% level probability respectively

Table 6. Phenotypic correlation coefficient matrix (rp) for 11 characters in lentil

Characters	Emergence of radicle	Emergence of plumule	Germination %	Shoot length at 20 th day	Root length at 20 th day	Fresh shoot weight	Fresh root weight	Dry shoot weight	Dry root weight	SVI I	SVI II
Emergence of radicle	-	0.27*	-0.24 NS	-0.02 NS	-0.04 NS	-0.11 NS	-0.05 NS	-0.04 NS	-0.04 NS	-0.16 NS	-0.13 NS
Emergence of plumule		-	-0.22 NS	-0.07 NS	0.09 NS	-0.1 NS	-0.17 NS	0.01 NS	-0.1 NS	-0.005 NS	-0.09 NS
Germination %			-	0.27*	0.31*	0.27*	0.09 NS	0.25*	0.11 NS	0.73**	0.79**
Shoot length at 20th day				-	0.48**	0.74**	0.19 NS	0.67**	0.32**	0.55**	0.56**
Root length at 20th day					-	0.42**	0.14 NS	0.35**	0.26*	0.69**	0.53**
Fresh shoot weight						-	0.18 NS	0.89**	0.33**	0.51**	0.64**
Fresh root weight							-	0.2 NS	0.82**	0.15 NS	0.31*
Dry shoot weight								-	0.34**	0.44**	0.71**
Dry root weight									-	0.22 NS	0.38**
SVI I										-	0.79**
SVI II											-

* and ** significant at 5% and 1% level probability respectively

CONCLUSION

This study recommends prioritizing traits like germination percentage, shoot and root length at 20th day, fresh and dry shoot weight, dry root weight, and seedling vigor indices for enhanced vigor and quality.

REFERENCES

- Al Ha Jibouri, H., Miller, P. A. and Robinson, H. F.** (1958). Genotypic and environmental variances and covariances in an upland Cotton cross of interspecific origin. *Agronomy journal*, **50**(10), 633-636.
[Google Scholar](#)
- Allard, R. W.** (1960). Principles of Plant Breeding. John Wiley and Sons. Inc. New York. *among seed yield traits and oil content in Ethiopian linseed germplasm. Introduction Journal Sustainable Crop Production*, **4**(4), 8-16.
[Google Scholar](#)
- Burton, G. W. and Devane, D. E.** (1953). Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy journal*, **45**(10), 478-481.
[Google Scholar](#)
- Crippa, I., Bermejo, C., Espósito, M. A., Martin, E. A., Cravero, V., Liberatti, D. and COUNTRY, E. L.** (2009). Genetic variability, correlation and path analyses for agronomic traits in Lentil genotypes. *International Journal of Plant Breeding*, **3**(2), 76-80.
[Google Scholar](#)
- Das, A., Babu, S., Yadav, G. S., Ansari, M. A., Singh, R., Baishya, L. K. and Ngachan, S. V.** (2016). Status and strategies for pulses production for food and nutritional security in north-eastern region of India. *Indian Journal of Agronomy*, **61**, 43-57.
[Google Scholar](#)
- Gleridou, A., Tokatlidis, I and Polidoros, A.** (2022). Genetic variation of a lentil (*Lens culinaris*) landrace during three generations of breeding. *Applied Sciences*, **12**(1), 450.
[Google Scholar](#)
- Idrissi, O., Houasli, C., Udupa, S. M., De Keyser, E., Van Damme, P. and De Riek, J.** (2015). Genetic variability for root and shoot traits in a lentil (*Lens culinaris* Medik.) recombinant inbred line population and their association with drought tolerance. *Euphytica*, **204**, 693-709.
[Google Scholar](#)
- Johnson, H. W., Robinson, H. F. and Comstock, R. E.** (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy journal*, **47**(7), 314-318.
[Google Scholar](#)
- Kumar, J., Srivastva, E. and Singh, M.** (2013). Genetics of early growth vigour in lentil (*Lens culinaris* Medik.). *Journal of Genetics*, **92**, 323-326.
[Google Scholar](#)
- Kumawat, K. R., Gothwal, D. K., Kumawat, R., Choudhary, M. and Kumawat, S.** (2018). Determination of salinity tolerance in lentil (*Lens culinaris* M.) seedlings using salt tolerance index. *Int J Chem Studies*, **6**(1), 1584-1589.
[Google Scholar](#)
- Laskar, R. A., Khan, S., Deb, C. R., Tomlekova, N., Wani, M. R., Raina, A. and Amin, R.** (2019). Lentil (*Lens culinaris* Medik.) diversity, cytogenetics and breeding. *Advances in Plant Breeding Strategies: Legumes*: **7**, 319-369.
[Google Scholar](#)
- Lerner, I. M.** (1958). *The Genetic Theory of Selection*. John Wiley, New York.
[Google Scholar](#)
- Manjeet, P. K., Sheoran, R. K., Nain, M. and Avtar, R.** (2020). Evaluation of sesame (*Sesamum indicum* L.) genotypes for genetic variability based on different traits under rainfed conditions. *Electronic Journal of Plant Breeding*, **11**(01), 54-59.
[Google Scholar](#)
- Panse, V. G. and Sukhatme, P. V.** (1957). Statistical Methods for Agricultural Workers, Ed.'1. *Indian Council of Agricultural Research, New Delhi*. p, 63-69.
[Google Scholar](#)
- Priya, S., Bansal, R., Kumar, G., Dikshit, H. K., Kumari, J., Pandey, R. and Kumar, A.** (2021). Root trait variation in lentil (*Lens culinaris* Medikus) germplasm under drought stress. *Plants*, **10**, 2410.
[Google Scholar](#)
- Sah, D., Kumar, M. and Singh, S.** (2020). Evaluation of lentil varieties under foot hill of north east agro-ecological region of India. *Journal of Pharmacognosy and Phytochemistry*, **9** (5), 1084-1087.
[Google Scholar](#)
- Sarker, A., Erskine, W. and Singh, M.** (2005). Variation in shoot and root characteristics and their association with drought tolerance in lentil landraces. *Genetic Resources and Crop Evolution*, **52**, 89-97.
[Google Scholar](#)
- Singh, M., Kumar, S., Basandrai, A. K., Basandrai, D., Malhotra, N., Saxena, D. R. and Singh, K.** (2020). Evaluation and identification of wild lentil accessions for enhancing genetic gains of cultivated varieties. *PLoS One*, **15**(3), e0229554.
[Google Scholar](#)
- Sumathi, P. and Muralidharan, V.** (2010). Inheritance of branching and important biometrical traits in sesame (*Sesamum indicum* L.). *Indian Journal of Genetics and Plant Breeding*, **70** (01), 112.
[Google Scholar](#)

