Original Research Article

STUDIES ON METROGLYPH ANALYSIS FOR MORPHOLOGICAL VARIATIONS OF GREENGRAM [*Vigna radiata* (L.) WILCZEK] GERMPLASM

Comment [m1]: **STUDIES ON GENETIC VARIABILITY AND MORPHOLOGICAL VARIATIONS OF GREENGRAM [*Vignaradiata*(L.) WILCZEK]GERMPLASM**

ABSTRACT

Greengram [*Vignaradiata* (L.) Wilczek] belongs to the family of Leguminosae (Fabaceae) is an important annual legume crop widely cultivated in semi-arid tropics. In the present investigation, a total of 20 lines of greengram including one check variety were evaluated during *Zaid*, 2023 in Randomized Block Design with three replications for genetic variability, heritability, and genetic advance by using 13 quantitative traits and to study morphological variation for these 13 quantitative characters by metroglyphand index score method. Analysis of variance for various quantitative characters revealed that the mean sum of squares due to genotypes showed high significant differences for all characters under study at 1% level and 5% level of significance. High GCV, PCV, heritability, and genetic advance were recorded by number of pods per plant. Based on metroglyph analysis and scatter diagram, 20 genotypes were grouped into 5 complexes, and the maximum number of genotypes (15) were found in group I. The two most variable characters, number of pods per plant and plant height (cm) were selected for the X and Y axes, respectively. The germplasm lines VIRAT (31), CO-7 (31), LGG-407 (30), AMULYA (29) and IPM-2-3 (29) recorded high index scores and fell into different clusters do well for morphological variations for a greater number of traits.Thus, the use of these genotypes in future breeding programs for crossing to obtain maximum variability of good combinations is suggested.

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Keywords:Genetic variability,PCV, GCV, Genetic Advance, Heritability,Metroglyph, Index score.

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1. INTRODUCTION

Pulses, often regarded as "Poor man's meat" are consideredthe earliest domestic plants and are the richest source of protein, starch, minerals, and vitamins and are a major source of human food second only to cereals (Poaceae). Greengram [*Vignaradiata* (L.) Wilczek], commonly called mung bean, is also known as "Golden gram", is one of the most ancient and extensively grown leguminous crops of India (2n=22 and genome size of 494 to 579 Mb). It is the third most important pulse crop after chickpea and pigeonpea, cultivated throughout India for its multipurpose uses as a vegetable, pulse, fodder, and green manure crop. Its seed is more palatable, nutritive, digestible, and nonflatulent than other pulses grown in the world**(Kartik *et al*., 2020).**Greengram is primarily a native of India and Central Asia may be a secondary center. There are around 7.3 million hectaresof mungbean cultivated worldwide, with an average production of 721 kg/ha and. 30% of the 5.3 million tonnes of production produced globally is split between India and Myanmar. China, Indonesia, Thailand, Kenya, Tanzania, Nepal, Sri Lanka, Korea, and Pakistan are other significant producers **(Nair *et al*., 2020)**. In India, the mungbean alone accounts for 10% of production (17 lakh tonnes) with productivity of 500 kg/ha and 16% of area (36 lakh hectares) ofall pulses. The dominant contributors to mungbean cultivation in terms of area and production are Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Odisha, Bihar, Tamil Nadu, Gujarat, Andhra Pradesh, and Telangana as stated in the **Annual Report (2022-23) by AICRPR on Kharif pulses**.

In particular, due to poor management and low soil fertility, greengram produces low seed yield and poor growth. However, the yield potential of this crop continues to be low and for this reason, it is facing severe competition from cereal crops, more particularly in recent years with the availability of high-yielding cereal varieties. The presently grown cultivars of mungbean are mostly old land races which are the products of direct and indirect natural and human selections. Due to this unique position in our agricultural system, the crop yield is very low at present. Recently, with the awareness of this reason, intensive work has been initiated to conserve and create diversity and thereby improve the crop.The success of any crop Improvement program largely depends on the selection of diverse parents as breeding material. Genetic diversity has been considered as an important factor which is also an essential prerequisite for hybridization programs or obtaining high-yielding progenies. The inclusion of diverse parents in the hybridization program will serve the purpose of combining desirable genes to obtain superior recombinants**(Johnson *et al*., 1955).** Estimation of genetic variability used in conjunction with heritability and genetic advance gives an idea of the possible improvement obtained through selection. High heritable estimates together with genetic advance are more valid for selection than heritability estimates alone. In view of that, it is therefore appropriate to assess the proportion of genetic and non-genetic variability observed in the traits studied. Exploitation of genetic variability in available germplasm is taken as a key point for making further genetic improvements in economically important traits as well as yield.

This diversity not only results in inducing genetic variation but also provides scope for new recombination of genes within the existing gene pool. Hence, studies on genetic diversity are of considerable importance to classify the available genotypes into discrete classes so that the parents belonging to diverse groups can be selected. In addition to aiding in the selection of divergent parents for hybridization, metroglyph analysis is a favorable tool for use in plant breeding as it measures the degree of divergence at the genotypic level and determines the relative contribution of each component character to the total divergence**(Anderson, 1957)**. The presence of genetic variability is of utmost importance for any breeding program and due to this reason,plant breeders have emphasized the evaluation of germplasm for the improvement of crop yield as well as for utilization in further breeding programs. Knowledge of genetic divergence coupled with genetic parameters and genetic gain obtained by selection is an important prerequisite for a systematic breeding program to improve the yield potential of genotypes.

1.1 OBJECTIVES

1. To determine the extent of genetic variation for morphological traits in Greengram.
2. To identify the divergence pattern of greengramgermplasm to develop selection-criteria for future hybridization programs.
3. To classify genotypes by metroglyph and index score analysis for morphological characters in Greengram.

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2. MATERIALS AND METHODS

The present investigation was carried out at the Research Farm,Department of Geneticsand Plant Breeding, SHUATS, Prayagraj, during the *Zaid* season2023.The experimental material comprises 20 genotypes alongwith one check variety.Threereplicationsofarandomized completeblock designwereusedforthe experiment in three replications with row-to-row spacing of 30 cm and plant-to-plant spacing of 10 cm and a plot size of 1m x 1m.For this greengram crop, recommended agronomical and plant protection practices were followed.

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To select the best yield-giving genotype in the agro-climatic conditions of Prayagraj region, observation was recorded by selecting five plants randomly from each genotype in each replication for various quantitative traits like plant height, days to 50% flowering, days to 50% pod setting, days to maturity, plant height (cm), number of primary branches, number of clusters per plant, number of pods per plant, pod length (cm), number of seeds per pod, seed index (g), biological yield (g),harvest index (%) and seed yield per plant (g).Thereafter,thephenotypic quantitativetraitswerecomparedwithhigh-yieldingcheckvarietiesforvarietalselection. For the analysis of morphological characters in different crop species, metroglyph and index score method advocated by Anderson (1957) has been used. During the study, used genotype were:

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1. VBN-3, 2. SML-1668, 3. SM-20-108, 4. MH-421, 5. SM-20-103, 6. TM-96-2, 7. LGG-460, 8. SHIKHA, 9. CO-8, 10. PUSA-105, 11. CO-7, 12. MGG-295, 13. IPM-2-14, 14. SHAKTI, 15. LGG-450, 16. IPM-2-3, 17. AMULYA, 18. PUSA BAISAKHI, 19. LGG-407, 20. **VIRAT (CHECK VARIETY)**

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CHART 1. EXPERIMENTAL DETAILS

Season	:	*Zaid*, 2023
Crop	:	Greengram (*Vignaradiata*(L.) Wilczek)
Experimental Design	:	Randomized Block Design (RBD)
Totalnumber of genotypes	:	20 (19+1 check)
Total number of replications	:	3
Total number of plots	:	60
Plot size	:	1m x 1m = 1m^2
Grosscultivatedarea	:	131.5 m^2
Netcultivatedarea	:	60 m^2
Row-to-row distance	:	30 cm
Plant-to-plant distance	:	10 cm

Date of Sowing	:	28 Feb 2023
Recommended Dose of Fertilizer (RDF)	:	@ 20:40:20 NPK kg/ha
Date of Harvesting	:	13 May 2023

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3. RESULT & DISCUSIION

3.1

ANALYSIS OF VARIANCE

Significant differences among the genotypes for all the traits have been observed in the analysis of variance. Analysis of variance for various quantitative characters revealed that the mean sum of squares due to genotypes showed high significant differences for all characters under study at 1% level and 5% level of significance. This reveals that the quantitative characters studied seem to have considerable genetic variability. Thus, there is an ample scope for improvement of different quantitative traits through selection. Based on the mean performance, seed yield per plant was observed high for CO-7 (15.57), AMULYA (14.453), and IPM-2-14 (14.15)

3.2PHENOTYPIC AND GENOTYPIC COEFFICIENT OF VARIATION

The variability is classified as low if the coefficient of variation is (< 10%), moderate (10-20%) and high (> 20%)**(Robinson *et al.* 1949)**. High estimates of genotypic coefficient of variation (GCV) were recorded for number of pods per plant (27.38). The moderate GCV was recorded for seed yield per plant (17.04), number of seeds per pod (14.11), biological yield per plant (14.02), seed index (13.24), plant height (13.10), number of clusters per plant (12.70), pod length (12.30) and number of primary branches per plant (10.50). Low GCV was recorded for days to maturity (4.96), days to 50% pod setting (6.78), days to 50% flowering (8.02), and harvest index (8.90).

High estimates of phenotypic coefficient of variation (PCV) were recorded for number of pods per plant (31.32) and seed yield per plant (20.43). The moderate PCV was recorded for biological yield per plant (17.20), number of seeds per pod (16.07), number of clusters per plant (15.87), plant height (14.76), pod length (14.07), seed index (13.37), number of primary branches per plant (12.44) and harvest index (10.07). Low PCV was recorded for days to maturity (6.46), days to 50% pod setting (7.21), and days to 50% flowering (9.74).

The estimates of phenotypic coefficient of variation were found higher than their corresponding genotypic coefficient of variation indicating that apparent variation is not only due to genotype but also due to the influence of the environment. Therefore, caution has to be exercised in making the selection based on phenotype alone can be effective for the improvement of these traits. Relatively higher differences between genotypic and phenotypic coefficient of variation were observed for number of pods per plant, seed yield per plant, biological yield per plant, and number of clusters per plant. The large difference between the GCV and PCV indicatesa high environmental influence on the expression of particular traits.

Table 1: Analysis of Variance for 13 quantitative characters in Greengram

Sl. No.	Source	Mean Sum of Squares (MSS)		
		Replication	Treatment	Error
	Degrees of freedom	2	19	38
1	Days to 50% flowering	0.3170	29.996**	4.089
2	Days to 50% pod setting	8.717**	39.628**	1.646
3	Plant height (cm)	0.0350	43.101**	3.55
4	Number of branches per plant	0.010	1.314**	0.156
5	Days to maturity	8.150	45.168**	8.483
6	Number of clusters per plant	0.4720	1.968**	0.31
7	Number of pods per plant	5.2670	219.846**	20.517
8	Number of seeds per pod	0.730	7.311**	0.657
9	Pod length (cm)	0.1290	2.833**	0.264
10	Seed Index (g)	0.0090	0.711**	0.004
11	Biological yield per plant (g)	13.9130	48.436**	6.983
12	Harvest Index (%)	1.7860	47.114**	4.02
13	Seed yield per plant (g)	3.2270	12.727**	1.619

*** Significant at 5% level of significance**

**** Significant at 1% level of significance**

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Table 2: Mean and Index Scores for 13 characters of 20 greengramgenotypes during *Zaid*, 2023

Sl.	Genotypes	DF 50%	DP 50%	PH	NPBP	DM	NCP	NPP	NSPD	PDL	SI	BYP	HI	SYP	TIS
1	**VBN-3**	36(2.00)	48.67(1.00)	27.2(2.00)	5.85(2.00)	69(2.00)	5.67(2.00)	34.02(2.00)	11.73(2.00)	6.93(2.00)	3.66(2.00)	26.5(2.00)	41.5(2.00)	11.01(2.00)	25
2	**CO-8**	32.67(1.00)	46.67(1.00)	28.13(2.00)	6.86(3.00)	65.67(1.00)	5.07(2.00)	20.97(1.00)	10.93(2.00)	8.71(3.00)	4.9(3.00)	23.92(2.00)	49.43(3.00)	11.82(2.00)	26
3	**LGG-407**	37.67(2.00)	53.67(2.00)	28(2.00)	6.68(3.00)	76.67(3.00)	6.73(3.00)	50.29(3.00)	11.07(2.00)	7.17(2.00)	3.64(2.00)	30.15(2.00)	43.31(2.00)	13.06(2.00)	30
4	**PUSA**	36.33(2.00)	51.33(2.00)	29(2.00)	5.91(2.00)	72.67(2.00)	6(2.00)	22.83(2.00)	10.33(2.00)	7.61(2.00)	3.36(2.00)	24.77(2.00)	44.64(2.00)	11.03(2.00)	26
5	**AMULYA**	37.33(2.00)	58.33(3.00)	25.67(2.00)	6.66(3.00)	71.33(2.00)	5.8(2.00)	23.32(2.00)	10.07(2.00)	7.54(2.00)	4.21(3.00)	25.81(2.00)	43.1(2.00)	11.17(2.00)	29
6	**IPM-2-3**	38(2.00)	59(3.00)	31.4(2.00)	6.27(2.00)	69.67(2.00)	6.13(2.00)	27.42(2.00)	12.86(3.00)	9(3.00)	4.14(2.00)	26.91(2.00)	38.63(2.00)	10.39(2.00)	29
7	**LGG-450**	30.67(1.00)	57.67(3.00)	20.83(1.00)	4.61(1.00)	62.33(1.00)	4.07(1.00)	13.89(1.00)	8.33(1.00)	6.07(1.00)	3.81(2.00)	17.57(1.00)	45.13(2.00)	7.95(1.00)	17
8	**SHAKTI**	33.33(1.00)	49.67(2.00)	23.73(1.00)	5.99(2.00)	65.33(1.00)	6.46(2.00)	28.18(2.00)	9.93(2.00)	7.21(2.00)	4.16(3.00)	20.86(1.00)	44.19(2.00)	9.25(2.00)	23
9	**IPM-2-14**	39.67(2.00)	50.33(2.00)	25.47(2.00)	6.25(2.00)	70(2.00)	5.93(2.00)	24.98(2.00)	11.33(2.00)	7.83(2.00)	2.93(1.00)	23.59(2.00)	44.61(2.00)	10.49(2.00)	25
10	**MGG-295**	33.33(1.00)	51.67(2.00)	26.67(2.00)	5.41(2.00)	69.33(2.00)	5.93(2.00)	32.7(2.00)	8.66(1.00)	6.76(2.00)	3.4(2.00)	23.09(2.00)	45.91(2.00)	10.6(2.00)	24
11	**CO-7**	38.67(2.00)	54.33(2.00)	37.4(3.00)	4.96(1.00)	72.33(2.00)	6.27(2.00)	44.86(3.00)	14.86(3.00)	10.1(3.00)	3.22(2.00)	33.88(3.00)	45.93(2.00)	15.57(3.00)	31
12	**PUSA-105**	36.67(2.00)	48.33(1.00)	25.48(2.00)	5.27(2.00)	75.67(3.00)	5.26(2.00)	32.29(2.00)	11.07(2.00)	6.87(2.00)	3.27(2.00)	29.75(2.00)	41.78(2.00)	12.43(2.00)	26
13	**VIRAT**	41.33(3.00)	52.67(2.00)	27.67(2.00)	6.4(2.00)	74.67(3.00)	7.4(3.00)	35.14(2.00)	10.8(2.00)	8.22(2.00)	3.27(2.00)	31.94(3.00)	44.38(2.00)	14.15(3.00)	31
14	**SHIKHA**	41.33(3.00)	56(2.00)	28.6(2.00)	5.78(2.00)	74(2.00)	5.8(2.00)	35.58(2.00)	8.77(1.00)	6.49(1.00)	3.31(2.00)	29.14(2.00)	44.09(2.00)	12.85(2.00)	25
15	**LGG-460**	40.67(3.00)	52(2.00)	29.87(2.00)	7.16(3.00)	71.33(2.00)	6.4(2.00)	29.71(2.00)	7.86(1.00)	8.31(2.00)	3.61(2.00)	27.51(2.00)	42.85(2.00)	11.79(2.00)	27
16	**TM-96-2**	33.33(1.00)	47.67(1.00)	25.33(2.00)	5.29(2.00)	65.33(1.00)	6.4(2.00)	27.22(2.00)	10.4(2.00)	7(2.00)	3.58(2.00)	24.98(2.00)	42.31(2.00)	10.59(2.00)	23
17	**SM-02-103**	32.33(1.00)	49.67(2.00)	26.13(2.00)	5.58(2.00)	66.33(1.00)	6.87(3.00)	38.89(3.00)	10.4(2.00)	6.97(2.00)	3.4(2.00)	32.43(3.00)	44.78(2.00)	14.45(3.00)	28
18	**MH-421**	36.33(2.00)	55.67(2.00)	29.73(2.00)	6.33(2.00)	70.67(2.00)	5.47(2.00)	27.16(2.00)	10.46(2.00)	6.7(2.00)	3.29(2.00)	28.47(2.00)	37.76(1.00)	10.73(2.00)	25
19	**SM-20-108**	39.67(2.00)	51(2.00)	23.27(1.00)	5.65(2.00)	72.67(2.00)	4.73(1.00)	25.18(2.00)	10.67(2.00)	7.02(2.00)	3.65(2.00)	24.43(2.00)	34.46(1.00)	8.39(1.00)	22
20	**SML-1668**	37.33(2.00)	55(2.00)	34.6(3.00)	5.47(2.00)	74(2.00)	4.67(1.00)	20.83(1.00)	10.53(2.00)	7.98(2.00)	4.46(3.00)	24.67(2.00)	32.9(1.00)	8.12(1.00)	24

DF 50% = days to 50% flowering, DP 50%= days to 50% pod setting, PH= plat height (cm), NPBP= number of primary branches per plant, DM= days to maturity, NCP= number of clusters per plant, NPP= number of pods per plant, NSPD= number of seeds per pod, PDL= Pod Length (cm), SI= Seed Index (g), BYP= biological Yield per Plant, HI= Harvest Index, SYP= Seed Yield per Plant, TIS= total Index Score

3.3 HERITABILITY

The heritability is classified as low (< 30%), moderate (30- 60%) and high (> 60%) by **Johnson *et al*., 1955**. In the present study, heritability estimates were high for seed index (98.204), days to 50% pod setting (88.492), plant height (78.786), harvest index (78.134), number of seeds per pod (77.139), pod length (76.458), number of pods per plant (76.406), number of primary branches per plant (71.223), seed yield per plant (69.582), days to 50% flowering (67.868), biological yield per plant (66.429) and number of clusters per plant (64.044) while it was moderate for days to maturity (59.04). No characters were observed with low heritability.

Higher values of broad sense heritability for the traits indicate that those characters are less influenced by environmental effects thus helping in the effective selection of the traits based on the phenotypic expression by adopting a simple selection method and suggesting the scope of genetic improvement.

3.4GENETIC ADVANCE AS PERCENT OF MEAN

Genetic advance as percent of mean was categorized as low (less than 10%), moderate (10-20%), and high (more than 20%) (**Johnson *et al*., 1955)**. In the present investigation, characters number of pods per plant (49.30), seed yield per plant (29.28), seed index (27.04), number of seeds per pod (25.53), plant height (23.96), biological yield per plant (23.54), pod length (22.16) and number of clusters per plant (20.94) recorded high genetic advance as percent of mean. While it was recorded as moderate for number of primary branches per plant (18.25) followed by harvest index (16.21), days to 50% flowering (13.61), and days to 50% pod setting (13.14) and it was recorded as low for days to maturity (7.86). Respectively suggesting that these characters might be viewed as desirable features for selection improvement, which may be attributed to additive gene action and so could be improved upon by modifying selection without progeny testing.

Table 3: Genetic Variability Parameters of 13 quantitative characters in greengram

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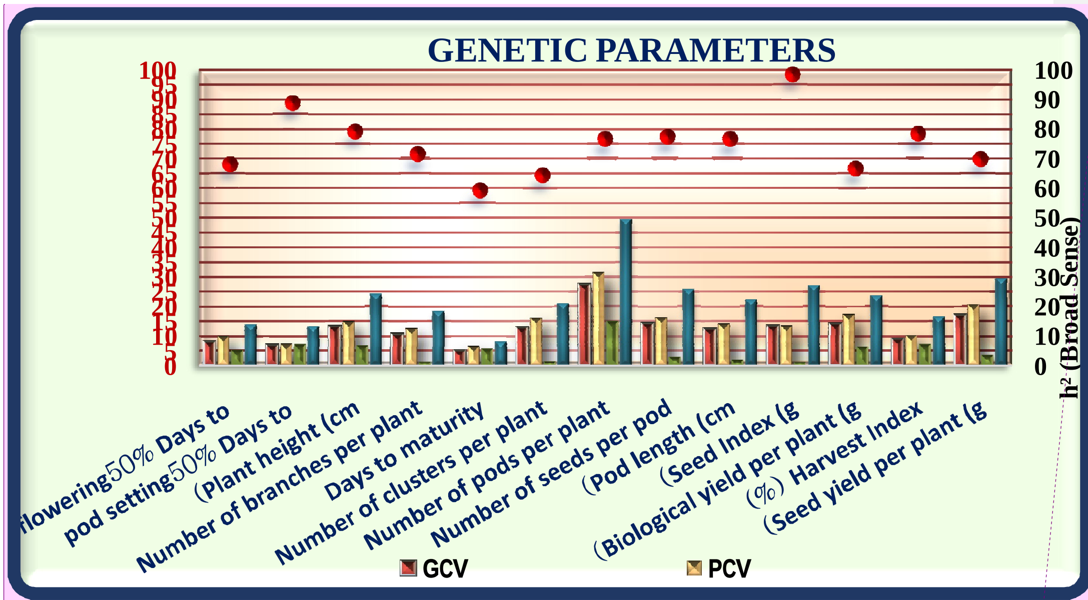
Sl. No.	Genetic Parameters	GCV	PCV	h^2 (bs)	GA	GAM
1	**Days to 50% flowering**	8.02	9.74	67.868	4.99	13.61
2	**Days to 50% pod setting**	6.78	7.21	88.492	6.90	13.14
3	**Plant height (cm)**	13.10	14.76	78.786	6.64	23.96
4	**Number of branches per plant**	10.50	12.44	71.223	1.08	18.25
5	**Days to maturity**	4.96	6.46	59.04	5.54	7.86
6	**Number of clusters per plant**	12.70	15.87	64.044	1.23	20.94
7	**Number of pods per plant**	27.38	31.32	76.406	14.68	49.30
8	**Number of seeds per pod**	14.11	16.07	77.139	2.70	25.53
9	**Pod length (cm)**	12.30	14.07	76.458	1.67	22.16
10	**Seed Index (g)**	13.24	13.37	98.204	0.99	27.04
11	**Biological yield per plant (g)**	14.02	17.20	66.429	6.24	23.54
12	**Harvest Index (%)**	8.90	10.07	78.134	6.90	16.21
13	**Seed yield per plant (g)**	17.04	20.43	69.582	3.31	29.28

PCV: Phenotypic Coefficient of Variation, GCV: Genotypic Coefficient of Variation, h^2bs: heritability (broad sense), GA: Genetic Advance, GAM: Genetic Advance as Percent of

Mean



Comment [m16]: the histogram needs some adjustments

Fig. 1: Histogram depicting GCV, PCV, heritability, and genetic advance for 13 quantitative characters of greengram genotypes

3.5 METROGLYPH ANALYSIS

Anderson's metroglyph analysis is a semi-graphical method for assessing the pattern of morphological variation in germplasm lines.It was observed that maximum variability was in number of pods per plant (13.89-50.29) followed by plant height (20.83-37.4), harvest index (32.9-49.43), biological yield per plant (17.57-33.88) and days to maturity (62.33-76.67). The range of mean values was utilized to assess the index scores 1, 2, and 3 for all the characters studied. The simple circle without rays represents index score 1, while others with values for index scores 2 and 3 have short and long rays on respective circles in different directions, respectively. The total index score varied from 17 (LGG-450) to 31 (CO-7, **VIRAT**) with a mean of 25.8. The highest total index score of 31 was recorded in genotypes CO-7 and **VIRAT (CHECK)** followed by a total index score of 30 in LGG-407 and a total index score of 29 in AMULYA and IPM-2-3. Hence, among the 20 germplasm lines, CO-7, VIRAT (CHECK), LGG-407, AMULYA, and IPM-2-3 were observed as high-yielding and identified for the highest index scores.In all these genotypes, number of pods per plant, plant height,and harvest index were contributory characters for more index scores.

Table 4: Index scores and signs used for characters for Metroglyph analysis of 20 genotypes of Greengram

Sl. No.	Character	Range of Mean	Score 1	Sign	Score 2	Sign	Score 3	Sign
			Value <		Value from - to		Value >	
1	Days to 50% flowering	30.67-41.33	33.47		33.47-39.8		39.80	
2	Days to 50% pod setting	46.67-59	48.83		48.83-56.1		56.10	
3	Plant height (cm)	20.83-37.4	23.92		23.92-31.5		31.50	
4	Number of branches per plant	4.61-7.16	5.26		5.26-6.58		6.58	
5	Days to maturity	62.33-76.67	66.57		66.57-74.33		74.33	
6	Number of clusters per plant	4.07-7.4	5.04		5.04-6.66		6.66	
7	Number of pods per plant	13.89-50.29	21.21		21.21-38.33		38.33	
8	Number of seeds per pod	7.86-14.86	8.99		8.99-12.11		12.11	
9	Pod length (cm)	6.07-10.1	6.55		6.55-8.5		8.50	
10	Seed Index (g)	2.93-4.9	3.18		3.18-4.15		4.15	
11	Biological yield per plant (g)	17.57-33.88	22.50		22.5-30.54		30.54	
12	Harvest Index (%)	32.9-49.43	38.62		38.62-46.55		46.55	
13	Seed yield per plant (g)	7.95-15.57	9.23		9.23-13.35		13.35	

Table 5: Mean and Index Scores for 13 characters of 20 greengramgenotpyes

Sl.	Genotypes	DF 50%	DP 50%	PH	NPBP	DM	NCP	NPP	NSPD	PDL	SI	BYP	HI	SYP	TIS
1	**VBN-3**	36(2.00)	48.67(1.00)	27.2(2.00)	5.85(2.00)	69(2.00)	5.67(2.00)	34.02(2.00)	11.73(2.00)	6.93(2.00)	3.66(2.00)	26.5(2.00)	41.5(2.00)	11.01(2.00)	25
2	**CO-8**	32.67(1.00)	46.67(1.00)	28.13(2.00)	6.86(3.00)	65.67(1.00)	5.07(2.00)	20.97(1.00)	10.93(2.00)	8.71(3.00)	4.9(3.00)	23.92(2.00)	49.43(3.00)	11.82(2.00)	26
3	**LGG-407**	37.67(2.00)	53.67(2.00)	28(2.00)	6.68(3.00)	76.67(3.00)	6.73(3.00)	50.29(3.00)	11.07(2.00)	7.17(2.00)	3.64(2.00)	30.15(2.00)	43.31(2.00)	13.06(2.00)	30
4	**PUSA**	36.33(2.00)	51.33(2.00)	29(2.00)	5.91(2.00)	72.67(2.00)	6(2.00)	22.83(2.00)	10.33(2.00)	7.61(2.00)	3.36(2.00)	24.77(2.00)	44.64(2.00)	11.03(2.00)	26
5	**AMULYA**	37.33(2.00)	58.33(3.00)	25.67(2.00)	6.66(3.00)	71.33(2.00)	5.8(2.00)	23.32(2.00)	10.07(2.00)	7.54(2.00)	4.21(3.00)	25.81(2.00)	43.1(2.00)	11.17(2.00)	29
6	**IPM-2-3**	38(2.00)	59(3.00)	31.4(2.00)	6.27(2.00)	69.67(2.00)	6.13(2.00)	27.42(2.00)	12.86(3.00)	9(3.00)	4.14(2.00)	26.91(2.00)	38.63(2.00)	10.39(2.00)	29
7	**LGG-450**	30.67(1.00)	57.67(3.00)	20.83(1.00)	4.61(1.00)	62.33(1.00)	4.07(1.00)	13.89(1.00)	8.33(1.00)	6.07(1.00)	3.81(2.00)	17.57(1.00)	45.13(2.00)	7.95(1.00)	17
8	**SHAKTI**	33.33(1.00)	49.67(2.00)	23.73(1.00)	5.99(2.00)	65.33(1.00)	6.46(2.00)	28.18(2.00)	9.93(2.00)	7.21(2.00)	4.16(3.00)	20.86(1.00)	44.19(2.00)	9.25(2.00)	23
9	**IPM-2-14**	39.67(2.00)	50.33(2.00)	25.47(2.00)	6.25(2.00)	70(2.00)	5.93(2.00)	24.98(2.00)	11.33(2.00)	7.83(2.00)	2.93(1.00)	23.59(2.00)	44.61(2.00)	10.49(2.00)	25
10	**MGG-295**	33.33(1.00)	51.67(2.00)	26.67(2.00)	5.41(2.00)	69.33(2.00)	5.93(2.00)	32.7(2.00)	8.66(1.00)	6.76(2.00)	3.4(2.00)	23.09(2.00)	45.91(2.00)	10.6(2.00)	24
11	**CO-7**	38.67(2.00)	54.33(2.00)	37.4(3.00)	4.96(1.00)	72.33(2.00)	6.27(2.00)	44.86(3.00)	14.86(3.00)	10.1(3.00)	3.22(2.00)	33.88(3.00)	45.93(2.00)	15.57(3.00)	31
12	**PUSA-105**	36.67(2.00)	48.33(1.00)	25.48(2.00)	5.27(2.00)	75.67(3.00)	5.26(2.00)	32.29(2.00)	11.07(2.00)	6.87(2.00)	3.27(2.00)	29.75(2.00)	41.78(2.00)	12.43(2.00)	26
13	**VIRAT**	41.33(3.00)	52.67(2.00)	27.67(2.00)	6.4(2.00)	74.67(3.00)	7.4(3.00)	35.14(2.00)	10.8(2.00)	8.22(2.00)	3.27(2.00)	31.94(3.00)	44.38(2.00)	14.15(3.00)	31
14	**SHIKHA**	41.33(3.00)	56(2.00)	28.6(2.00)	5.78(2.00)	74(2.00)	5.8(2.00)	35.58(2.00)	8.77(1.00)	6.49(1.00)	3.31(2.00)	29.14(2.00)	44.09(2.00)	12.85(2.00)	25
15	**LGG-460**	40.67(3.00)	52(2.00)	29.87(2.00)	7.16(3.00)	71.33(2.00)	6.4(2.00)	29.71(2.00)	7.86(1.00)	8.31(2.00)	3.61(2.00)	27.51(2.00)	42.85(2.00)	11.79(2.00)	27
16	**TM-96-2**	33.33(1.00)	47.67(1.00)	25.33(2.00)	5.29(2.00)	65.33(1.00)	6.4(2.00)	27.22(2.00)	10.4(2.00)	7(2.00)	3.58(2.00)	24.98(2.00)	42.31(2.00)	10.59(2.00)	23
17	**SM-02-103**	32.33(1.00)	49.67(2.00)	26.13(2.00)	5.58(2.00)	66.33(1.00)	6.87(3.00)	38.89(3.00)	10.4(2.00)	6.97(2.00)	3.4(2.00)	32.43(3.00)	44.78(2.00)	14.45(3.00)	28
18	**MH-421**	36.33(2.00)	55.67(2.00)	29.73(2.00)	6.33(2.00)	70.67(2.00)	5.47(2.00)	27.16(2.00)	10.46(2.00)	6.7(2.00)	3.29(2.00)	28.47(2.00)	37.76(1.00)	10.73(2.00)	25
19	**SM-20-108**	39.67(2.00)	51(2.00)	23.27(1.00)	5.65(2.00)	72.67(2.00)	4.73(1.00)	25.18(2.00)	10.67(2.00)	7.02(2.00)	3.65(2.00)	24.43(2.00)	34.46(1.00)	8.39(1.00)	22
20	**SML-1668**	37.33(2.00)	55(2.00)	34.6(3.00)	5.47(2.00)	74(2.00)	4.67(1.00)	20.83(1.00)	10.53(2.00)	7.98(2.00)	4.46(3.00)	24.67(2.00)	32.9(1.00)	8.12(1.00)	24

DF 50% = days to 50% flowering, DP 50%= days to 50% pod setting, PH= plat height (cm), NPBP= number of primary branches per plant,DM= days to maturity, NCP= number of clusters per plant, NPP= number of pods per plant, NSPD= number of seeds per pod, PDL= Pod Length (cm), SI= Seed Index (g), BYP= biological Yield per Plant, HI= Harvest Index, SYP= Seed Yield per Plant, TIS= total Index Score

The scatter diagram has been prepared by takingnumber of pods per plant on the x-axis and plant height (cm) on the y-axis and five complexes could be distinguished based on morphological variations. The scatter diagram revealed that five complexes could be distinguished based on morphological variations.

Complex - I: was represented by 10 genotypes which are VBN-3, CO-8, PUSA BAISAKHI, AMULYA, IPM-2-3, SHAKTI, IPM-2-14, MGG-295, PUSA-105, VIRAT, SHIKHA, LGG-460, TM-96-2, MH-421 and SM-20-108 with moderate number of pods per plant with moderate plant height with range value of 21- 28 and average index score of the complex 25.73.

Complex – II was represented by two genotypes which are LGG-407 and SM-20-103 with higher number of pods per plant with moderate plant height with a range value of 28-30 and an average index score of the complex 29.

Complex – III: was represented by one genotype LGG-450 with lower number of pods per plant with lower plant height with range and average index score of the complex 17.

Complex – IV: was represented by one genotype CO-7 with moderate number of pods per plant with higher plant height with range and average index score of the complex 24.

Complex – V: was represented by one genotype SML-1668 with higher number of pods per plant with higher plant height with range and average index score of the complex 31.

Table 6: Genotypes in different complexes in metroglyph analysis

Complex	Name of complex	No. of lines	Name of lines	Range and average score
I	Moderate number of pods per plant with moderate plant height	15	VBN-3, CO-8, PUSA BAISAKHI, AMULYA, IPM-2-3, SHAKTI, IPM-2-14, MGG-295, PUSA-105, VIRAT, SHIKHA, LGG-460, TM-96-2, MH-421 and SM-20-108	22.00-31.00 (25.73)
II	Higher number of pods per plant with moderate plant height	2	LGG-407 and SM-02-103	28.00-30.00 (29.00)
III	Lower number of pods per plant with lower plant height	1	LGG-450	17
IV	Moderate number of pods per plant with higher plant height	1	CO-7	24
V	Higher number of pods per plant with higher plant height	1	SML-1668	31

Fig. 2: Scattered diagram of Metroglyph analysis showing 20 genotypes of greengram

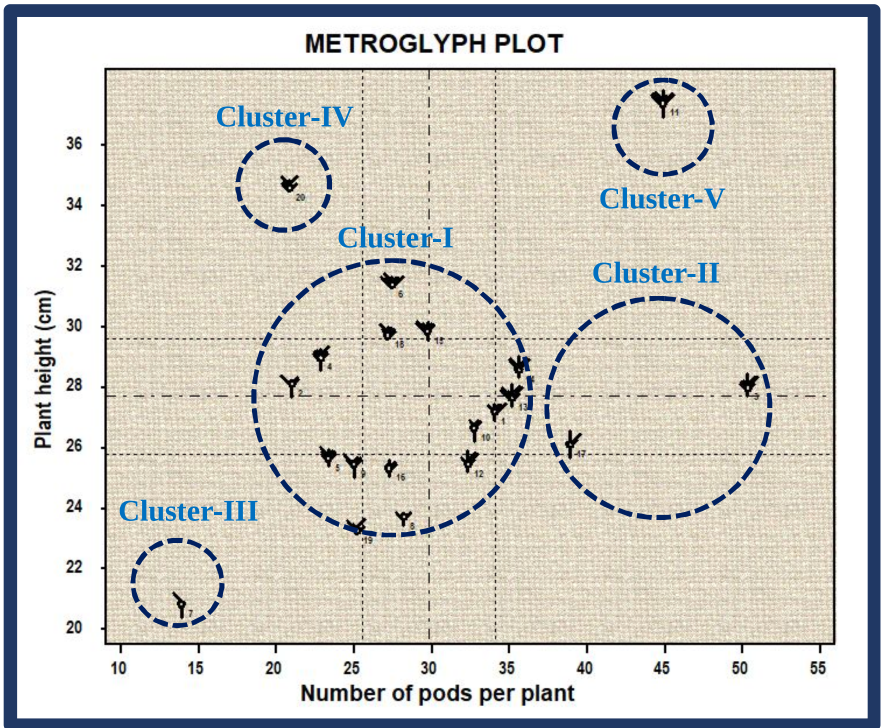
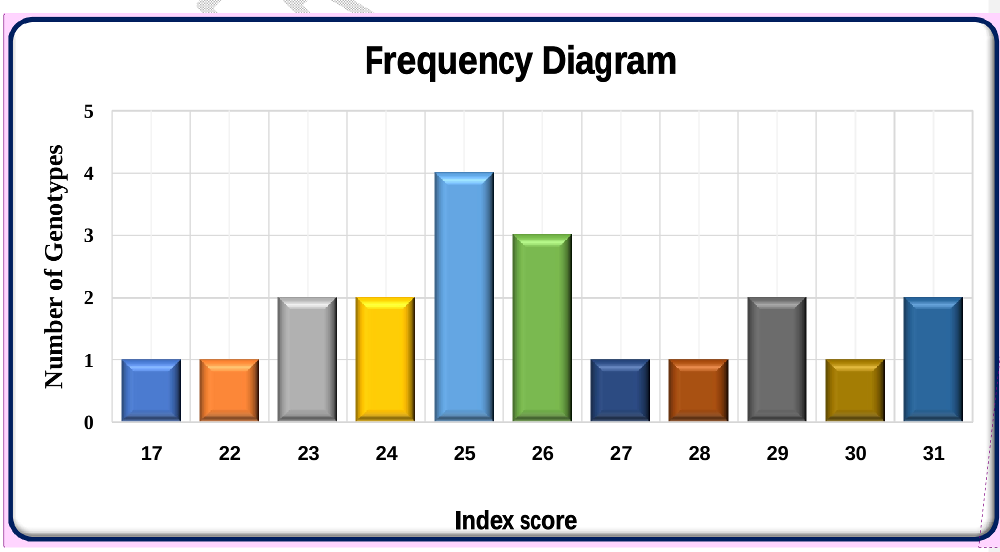


Fig. 3: Frequency diagram of index scores of 20 greengram genotypes



Comment [m17]: English number

4. CONCLUSION

From the present investigation, it is concluded that among the 20 genotypes of greengram based on mean performance, genotype CO-7 (15.573 g) possessed the maximum seed yield per plant over the check variety VIRAT (10.487 g). It is also concluded from the present study that all the 20 genotypes of the greengram showed significant differences among them for all the characters. Genotypes CO-7, AMULYA, IPM-2-14, SM-20-108, SHAKTI, and MGG-295 were identified as the best-performing genotypes for seed yield and its component characters. The highest GCV, PCV is recorded for number of pods per plant followed by seed yield per plant and biological yield. Also, the Phenotypic Coefficient of Variation values are higher than the Genotypic Coefficient of Variation for all the traits under study indicating the influence of environment on studied characters. Hence, the characters with high-range estimates of GCV should be given top priority during selection. The number of pods per plant recorded high variation among all other characters with high PCV and GCV and heritability coupled with genetic advance as percent of the mean. The scattered diagram was prepared for 20 greengramgermplasm lines, which formed five complexes, these complexes comprised 10, 2, 1, 1, and 1 germplasm lines respectively. Further, it can be concluded that the metroglyph technique was useful in identifying groups of genotypes with yield-enhancing traits among the collection of diverse genotypes thus suggesting its potential value in mungbean improvement. The germplasm lines CO-7, VIRAT, LGG-407, AMULYA, and IPM-2-3 recorded high index scores and fell into different clusters and can be used as parents in hybridization to have maximum variability of a good combination of characters.

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