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Research Article

Joint Regression Analysis of Variance for Seed Yield and its Attributing Traits by Eberhart and Russell (1966) Model in Black Gram (*Vigna mungo* L.) Under Rainfed Conditions of NW Himalaya's

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Abstract

Black gram (*Vigna mungo* L. Hepper) is a self-pollinated crop belonging to the leguminous family having high protein content. The present investigation was conducted during *kharif* 2021 at Pulses Research Sub-Station, Samba and Advanced Centre for Rainfed Agriculture (ACRA), Dhiansar of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu as Environment-I (E1), Environment-II (E2) and Environment-III (E3), respectively. The present experiments were executed to investigate the extent of genetic diversity and to identify promising genotypes for further utilization in the breeding program of black gram. The experimental materials were composed of thirty black gram genotypes which were planted in Randomized Complete Block Design (RCBD). The agro-morphological data were recorded of eleven traits from each environmental condition for plant height, number of days to 50% flowering, number of branches per plant, number of days to maturity, number of pods per plant, number of seeds per pod, pod length, number of clusters per plant, number of pods per cluster, 1000 seed weight and seed yield per plant. Stability analysis was done and followed the Eberhart and Russell model,1966. Genotype PU40 was the most stable genotype across the environments for 1000 seed weight, days to maturity and seed yield/plant. However, genotype PU35 was most stable for days to 50% flowering, days to maturity and number of pods/plant. These genotypes could be utilized in future breeding programme for seed yield/plant improvement in urdbean and pyramiding of components traits such as number of pods/ plant, 1000 seed weight, days to 50% flowering, days to maturity and seed yield/plant.

Keywords: Blackgram; Stability; Eberhart and Russell 1966

Introduction

Black gram or urdbean (*Vigna mungo* L. Hepper) is a short-duration grain legume with high protein content in seeds [6]. It belongs to the family Leguminosae, sub-family Papilionaceae. It is generally famously known as Urd/ Biri/ Mash, is one of the important nutrient-reach grain legumes that are exploited in the Indian diet, soil conservation, green fodder, integrated farming systems, reclaiming of degraded pastures, and symbiotic nitrogen fixation [2]. It is domesticated from *Vigna mungo* var. silvestris [10]. It is a self-pollinating diploid (2n = 2x = 22) annual crop with a small genome size of 574 Mbp [3]. It is believed to have the center of origin of black gram is India [15]. After gram and pea black gram is the third most important pulse crop in India. India is the largest producer and consumer of blackgram cultivated in an area 4.50 Mha with 2.83 MT production [7]. Blackgram is widely grown in Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, Rajasthan, and Gujarat during kharif season and Andhra Pradesh and West Bengal in rabi season [4]. In the Jammu division of UT of Jammu and Kashmir, black gram is cultivated over an area of 0.12 Mha with a production of 0.57 MT during the year 2016-17 [18]. It is a major pulse crop after Rajmash in the Jammu region of UT of Jammu and Kashmir. Major black gram growing districts of the Union Territory of Jammu and Kashmir are Kathua, Samba, Jammu, Udhampur, and some part of Bhadrwah and Doda. Among various pulses, black gram is a major source of higher dietary protein quantity for the major lactovegetarian population of India. Its grain contains about 24% protein, 60% carbohydrate, 1.3% fat, and phosphoric acid [10].

Blackgram's grain yield being a quantitative trait is highly influenced by the environment. Genotype × Environment interaction is the most commonly used statistical analysis for the evaluation of genotypes for yield performance over multi-environments for the selection of stable genotypes. The adaptability of the genotype to perform well over diverse environmental conditions is a requirement for the present era [1]. Genotypes with low G×E interaction and high yield are desirable for crop breeders as well as farmers because it indicates that the environments have less effect on the performance of genotypes and yield is greatly contributed by genetic component. The objectives of the present study were to investigate the performance and consistency of thirty black gram genotypes for eleven agro morphological traits over different days of sowing of black gram using [5] established a better model for assessing the suitability of variety in environments. According to this approach, the genotype x environment (G × E) interactions are divided into two sections: the slope of the regression line (b_i) and deviation from the regression line (S^2di). According to this model, a stable genotype has a higher mean value than then grand mean with unit regression (b_i = 1.00) and departure from the regression (S^2di = 0). With the concerns in mind, the present study was executed to identify the superior genotypes which are appropriate for the black gram cultivation areas of the Jammu region of UT of Jammu Kashmir.

Material and Methods

Material

The experimental material used in the present study comprised thirty different genotypes of black gram collected from Govind Ballabh Pant University of Agriculture and Technology Pantnagar, Uttarakhand (India). The pedigree and source of black gram genotypes included in the study are given in (Table 1).

Genotypes	Source	Pedigree	Year of release
AZAD-2	IIPR Kanpur	-	-
MASH- 114	PAU Ludhiana	Mash 338 × RBI 1	-
NU-1	NDUAT Faizabad	_	-
PU-07-7	GBPANT	BDYR-1 × DPU 88-31	-
PU-10	GBPANT	PU 19× KU 96-3	2019
PU-13-05	GBPANT	PU-31 × MASH 1008	2020
PU-15-2	GBPANT	ICU 14 × Mash 1008	Advanced breeding line (F_{10})
PU-15-21	GBPANT	Mash 144 × PU 2006-1	Advanced breeding line (F_{10})
PU-15-23	GBPANT	PU 40 × IPU 02-33	Advanced breeding line (F_{10})
PU-15-26	GBPANT	PU 31 × IPU 02-33	Advanced breeding line (F_{10})
PU-15-28	GBPANT	PU 31 × IPU 02-33	Advanced breeding line (F_{10})
PU-15-29	GBPANT	PU 31 × IPU 02-33	Advanced breeding line (F_{10})
PU-15-30	GBPANT	IPU 2006-1 × Mash 114	Advanced breeding line (F_{10})
PU-15-31	GBPANT	IPU 2006-1 × Mash 114	Advanced breeding line (F_{10})
PU-15-32	GBPANT	IPU 2006-1 × Mash 114	Advanced breeding line (F_{10})
PU-15-34	GBPANT	PU 40 × PU 09-30	Advanced breeding line (F_{10})
PU-15-35	GBPANT	PU 40 × PU 09-30	Advanced breeding line (F_{10})
PU-15-40	GBPANT	PU 31 × TU 94-2	Advanced breeding line (F_{10})
PU-17-4	GBPANT	PU 31 × PCPGR 8307 (Rice Bean)	Advanced breeding line (F_{10})
PU-19	GBPANT	UPU 1 × UPU 2	1981
PU-31	GBPANT	UPU 9710 × DPU 8831	2005
PU-35	GBPANT	UPU 3 × Pant U 19	1985
PU-40	GBPANT	UPU 89-6-7 × 7668/48	2005
PU-7	GBPANT	UPU 97-10 × KU 96-3	2019
PU-8	GBPANT	Pant U 19 × KU 303	2019
PU-9	GBPANT	UPU 97-10 × KU 96-3	2019
PU-IPU-2-43	GBPANT	-	Advanced breeding line (F_{10})
PU-KU-99-21	GBPANT	-	Advanced breeding line (F_{10})
PU-KUG216	GBPANT	-	Advanced breeding line (F_{10})
PU-UPU-97-1	GBPANT	-	Advanced breeding line (F_{10})

Table 1: List of genotypes along with pedigree and source used in research work.

Experiment site

Thirty genotypes of black gram were scrutinized at three different environmental conditions created with different dates of sowing during *kharif* 2021-22 at Pulses Research Sub-Station, Samba and Advanced Centre for Rainfed Agriculture (ACRA), Dhiansar of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu). Weather conditions during the cropping period (*i.e.,* July to November) at PRSS, Samba, and ACRA, Dhiansar were favorable for the growth and development of black gram. Total rainfall at PRSS, Samba, and ACRA Dhiansar during the cropping season was 5.16 mm and 39.5 mm, respectively from July 2021 to November 2021 (Table 2).

Month	Rainfall (mm)	
	PRSS, Samba	ACRA Dhiansar
July	2.71	11.6
August	0.59	18.3
September	1.86	9.1
October	-	0.5
November	-	-
Total	5.16	39.5

Table 2: Rainfall (mm) distribution during the cropping period at PRSS Samba and ACRA Dhiansar.

Experiment layout plan

The field experiments were conducted in Randomized Complete Block Design (RCBD) with three replications of plot size of two rows of each genotype of three-meter length. The description of each environment is given below in (Table 3).

Environment	Date of Sowing	Spacing	Location
E_1 Normal Sowing	14th July 2021	30 x 10 cm^2	Samba
E_2 Normal Sowing	15th July 2021	30 x 10 cm^2	Dhiansar
E_3 Late Sowing	04th August 2021	30 x 10 cm^2	Dhiansar

Table 3: Experiment Layout Plan.

Methods

Five healthy plants were randomly selected in each genotype, in each replication, and in each environment for agro-morphological data recording of plant height, number of days to 50% flowering, number of branches per plant, number of days to maturity, number of pods per plant, number of seeds per pod, pod length, number of clusters per plant, number of pods per cluster, 1000 seed weight and seed yield per plant. The pooled mean data were subjected to statistical analysis to analyze the variance and stability parameters employing R-Studio version 2022. Applying Bartlett's test for homogeneity, all three mean squares due to errors obtained for each attribute were validated for homogeneity. [5] of phenotypic stability was used for the study of genotype × environment interaction. The genotype x environment interactions observed for all the traits were utilized to compute phenotypic stability.

Results and Discussion

All eleven morpho-physiological characters, analysis of variance was appraised as per environment (E_1, E_2, E_3, and pooled). The outcomes (Table 4) implied that the variance attributable to genotypes was highly significant at five percent and one percent except for the number of days to 50% flowering in E_1. It means significant genetic variability was present among all 30 genotypes for agro-morphological traits under study.

Env.	Source	d.f	PH	DTF	NBP	DTM	NPP	NSP	PL	NCP	NPC	1000 SW	SYP
Location – 1: Pulse Research Sub-Station Samba; (14 July 2021)													
E_1	Replications	2	6.07	27.54	0.64	18.61	4.91	1.19	0.73	1.52	1.97	5.40	5.28
	Genotypes	29	194.70**	19.18*	5.66**	47.62**	70.74**	2.71**	4.05**	17.57**	4.30**	35.70**	4.33**
	Error	58	2.19	10.16	0.29	6.81	13.60	0.40	0.39	0.67	0.38	1.72	0.36
Location – 2: Advanced Centre for Rainfed Agriculture (ACRA) Dhiansar: 1st DOS; (15 July 2021)													
E_2	Replications	2	229.94	10.07	0.40	0.81	107.44	0.24	1.02	.1.80	0.69	4.59	1.54
	Genotypes	29	114.70**	19.94**	4.94**	18.95**	91.92**	5.10**	1.69**	11.29**	2.67**	71.97**	5.67**
	Error	58	21.62	4.87	0.41	7.44	11.48	0.43	0.33	0.74	0.33	1.68	0.55
Advanced Centre for Rainfed Agriculture (ACRA) Dhiansar: 2nd DOS; (1 August 2021)													
E_3	Replications	2	6.09	34.44	0.10	30.10	5.61	0.77	0.13	1.74	0.85	54.34	0.78
	Genotypes	29	63.28**	26.68**	4.61**	28.59**	105.21**	5.40**	3.41**	18.37**	1.60**	52.15**	5.29**
	Error	58	27.70	11.43	0.78	10.67	6.79	0.56	0.59	1.71	0.38	17.31	0.30

Table- 4: Environment wise analysis of variance for different Agro-morphological traits under rainfed conditions in blackgram (*Vigna mungo* L.). ** and * indicates levels of significance at 5% and 1% respectively

Note: d.f: Degrees of Freedom; PH: Plant Height (cm); DTF: Number of days to 50 % Flowering; NBP: Number of Branches Per Plant; DTM: Number of Days to Maturity; NPP: Number of Pods per Plant; NSP: Number of Seeds per pod; PL: Pod Length; NCP: Number of Clusters Per Plant; NPC: Number of Pods Per Clusters; 1000 SW (g): 1000 Seed Weight (g) and SYP: Seed Yield Per Plant (g).

The environments (E_1, E_2, E_3, and pooled) were validated for homogeneity of variances (Bartlett's chi-square test) prior to continuing further to the pooled analysis. The non-significant χ^2 values ascertained the homogeneity of variance owing to error throughout all eleven attributors examined. As a consequence, variance across the environments had been explored further (Table 5, 6). Most of the traits had significant variance owing to the environment. The variance due to genotype × environment (g × e) interactions were significant for all the traits, confirming the existence of genotype × environment (g × e) interactions, and hence work on predicting phenotypic stability has proceeded.

Source	d. f.	PH	DTF	NBP	DTM	NPP	NSP	PL	NCP	NPC	1000SW	SYP
Replications	2	80.7	24.02	0.38	16.51	12.4	0.74	0.63	1.69	1.17	21.45	2.54
Genotypes	29	181.7**	29.93**	10.10**	30.02**	151.4**	8.07**	4.96**	18.87**	4.29**	65.92**	9.27**
Environment	2	939.1**	1438.6**	15.49**	11545.7**	1495.4**	8.21**	12.74**	50.88**	66.75**	298.55**	27.30**
Genotype × Environment	58	95.5**	17.94**	2.55**	32.57**	58.2**	2.57**	2.10**	14.17**	2.14**	46.96**	3.01**
Residuals	174.00	17.2	8.82	0.50	8.31	10.6	0.46	0.44	1.05	0.36	6.91	0.40

Table 5: Pooled analysis of variance for different agro-morphological traits under rainfed conditions.

Source of variation	d. f.	PH	DTF	NBP	DTM	NPP	NSP	PL	NCP	NPC	1000 SW	SYP
Genotypes	29	60.56**	9.98**	3.36**	10.0**	50.47**	2.69**	1.65*	6.28**	1.43*	21.97**	3.09**
Env. + (Gen.* Env.)	60	41.21**	21.77**	1.99*	138.8**	35.38**	1.92*	1.81*	5.13**	1.43*	18.44**	2.27*
Environments (Lin.)	1	626.08**	959.05**	10.32**	7697.2**	996.93**	5.47*	8.49**	33.91**	44.49**	199.03**	18.20**
Geno. * Env. (Lin.)	29	27.43**	6.09**	1.98*	14.4**	19.15**	1.77*	1.58*	4.62**	1.92*	16.62**	1.71*
Pooled Deviation	30	35.04**	5.67**	1.70*	7.1**	19.02**	1.90**	1.78*	4.66**	1.49*	14.19**	1.25*
Pooled Error	180	5.53	2.84	0.16	2.7	3.42	0.14	0.14	0.33	0.11	2.22	0.13

Table 6: Joint regression analysis of variance for seed yield and its contributing traits by Eberhart and Russell (1966) model.

** and * indicates levels of significance at 5% and 1%, respectively.

Mean performance of genotypes on the pooled basis

Black gram is one of the important pulse crops grown in a wide range of agro-climatic conditions in the country. In the Jammu region, it is a major part of the diet along with rajmash. Mean values across the environments for the number of days to 50% flowering varied from 44.56 (PU-15-21) to 51.44 (PU-07-7) with a general mean of 48.30. Genotypes namely PU-10, PU-15-21, PU-15-23, PU-15-26, PU-15-29, PU-15-30, PU-15-31, PU-15-32, PU-15-34, and PU-15-35 revealed lower mean performance as compared to the general mean. It is denoted by the early flowering in black gram and directly helps in disease escape in this crop. However, genotype PU-07-7 exhibited the highest mean value (51.44) while genotype PU-15-21 revealed the lowest mean performance (44.56). The number of days to maturity exhibited mean performance ranged from 80.44 to 88.44. Genotypes namely PU-13-05, PU-15-23, PU-15-26, PU-15-30, PU-15-31, PU-15-32, PU-15-35, PU-9, PU-35, and PU-8 showed lower mean performance as compared to the general mean value (83.75). Lower mean performance as compared to general mean value prerequisite in the development of early maturing varieties. These genotypes shall be preferred to grow under rainfed conditions because these genotypes are early maturing and complete their life cycle prior to the start of the drought period. The mean value of the number of pods per plant varied from 28.54 to 43.87. Genotypes namely PU-15-2, PU-15-23, PU-15-26, PU-15-28, PU-15-35, PU-15-40 PU-31, PU-35, PU-9, and PU-IPU-2-43 revealed higher mean performance as compared to general mean 36.40. The highest mean performance was exhibited by genotype (PU-9) (43.87). Higher mean performance as compared to general mean helps in the development of high-yielding varieties. The number of clusters per plant ranged from 6.19 to 11.27. Genotypes namely AZAD-2, PU-15-2, PU-15-23, PU-19, PU-35, PU-8, PU-9, PU-KU-99-21, PU-15-KUG216, and PU-UPU-97-1 exhibited higher mean as compare to general mean 9.05. The highest mean value was revealed by the genotype PU-9 while genotype PU-IPU-2-43 had the lowest mean performance for the number of clusters per plant. Higher mean performance as compared to grand mean performance is responsible for the development of high-yielding black gram varieties. Mean performance for a trait, 1000 seed weight on pooled mean basis varied between 35.76 to 49.48. Genotypes namely AZAD-2, PU-10, PU-15-23, PU-15-26, PU-15-28, PU-15-32, PU-15-40, PU-7, PU-IPU-2-43, and PU-KU-99-21 exhibited higher mean performance as compared to general mean 43.38. However, genotype PU-KU-99-21 exhibited the highest mean performance (49.12) while genotype PU-15-21 exhibited the lowest mean performance (35.76) in respect of 1000 seed weight. These genotypes were higher in seed yield per plant due to their high 1000 seed weight. Similar conclusions were described by [21] in respect of the number of days to 50% Flowering, plant height, number of clusters per plant, number of pods per plant, pod length, number of seeds per pod, number of days to maturity and seed yield per plant while [8] for number of days to 50% flowering, plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, pod length, number of seeds per pod, seed yield per plant and protein content.

Stability parameters of individual genotypes:

The model, projected by [5] was applied to evaluate the phenotypic stability. Joint regression with reference to genotype's performance on an environmental indicator (b_i) is a common method to determining stability. Assessment of joint regression for eleven morpho-physiological characteristics has been inferred in table 7 and figure 1.

		PH			DTF			NBP			DTM		
1	AZAD-2	54.59	0.32	37.83	50.77	1.35	-2.73	6.67	-0.66	-0.15	85.66	1.22*	15.27
2	MASH- 114	61.12	2.06	-1.13	49.77	0.74	6.38	5.35	1.15	-0.05	85.22	0.91	-0.77
3	NU-1	59.78	2.66	35.24	50.44	0.40	1.20	4.7	0.65	1.35	86.33	1.38*	-2.65
4	PU-07-7	52.33	0.96	26.09	51.44	1.23	14.18	6.3	1.14	0.19	86.44	0.86	-0.09
5	PU-10	56	1.87	15.58	47.88	0.77	-2.89	5.78	-1.57	0.35	84	0.52	-2.40
6	PU-13-05	61.73	1.16	-5.66	49.55	1.44	-2.80	8.53	2.90*	0.32	81	1.10	-1.67
7	PU-15-2	66.32	0.21	6.61	49.44	0.95	-2.21	7.87	0.93	-0.94	85.55	0.96	4.71
8	PU-15-21	61.60	1.45	66.48	44.55	0.35	1.02	4.81	0.09	-0.07	88.44	0.32	-2.44
9	PU-15-23	47.63	-0.52	51.74	47.55	1.31	9.92	5.13	0.90	3.82	81.44	1.23*	0.57
10	PU-15-26	55.74	1.81	2.47	45.22	0.69	20.70	4.16	1.98	0.63	80.44	1.03	-2.11
11	PU-15-28	56.69	2.47	96.17	50.55	0.68	0.199	7.5	2.50	0.29	84.77	0.97	27.47
12	PU-15-29	56.10	-0.91	56.94	46.88	-0.10	2.09	5.51	-0.14	-0.15	85	0.92	5.70
13	PU-15-30	54.98	0.37	126.65	45.88	1.37	-2.90	4.66	2.79	0.26	83.66	0.78	-0.58
14	PU-15-31	48.55	-1.20	65.25	47.88	0.43	-2.29	4.67	2.12	0.91	82.88	0.87	3.39
15	PU-15-32	49.86	0.90	-5.51	44.77	1.18	21.07	4.67	3.91*	2.65	82.88	1.07	-2.47
16	PU-15-34	51.08	0.58	-4.82	46.66	0.60	0.08	5.96	-0.96	-0.09	83	1.32*	15.45
17	PU-15-35	52.25	-0.62	-5.58	46.88	1.17	-1.75	4.72	1.57	0.07	82.77	0.59	4.83
18	PU-15-40	51.61	-0.66	-1.75	48.66	0.84	-1.00	4.43	0.41	0.40	84.55	0.91	5.67
19	PU-17-4	62.09	2.50	-4.29	50	1.02	-2.93	5.2	4.09*	-0.14	83.55	1.25*	-1.95
20	PU-19	59.4	3.06	12.55	48.55	0.94	-2.59	6.58	2.43	0.15	82.55	1.01	-1.09
21	PU-31	53.25	0.34	54.00	47	1.30	-2.89	6.23	-0.50	2.22	81.22	0.95	1.41
22	PU-35	53.03	1.25	-5.68	49.11	1.10	6.93	4.91	2.46	-0.12	81.55	1.02	3.63
23	PU-40	57.22	-0.00	1.47	47.88	1.13	-2.84	5.4	-1.18	-0.14	84.33	1.00	6.73
24	PU-7	58.70	1.01	18.27	49.22	0.37	14.29	5.02	0.45	-0.16	82.55	0.77	1.96
25	PU-8	52.90	1.59	-3.13	49.33	1.29	0.80	4.81	3.41*	-0.05	83.22	1.10	3.75
26	PU-9	56.48	2.06	171.49	48.77	0.65	0.90	5.41	1.95	1.43	82.22	1.30*	-1.59
27	PU-IPU-2-43	56.93	0.21	2.03	47.66	1.27	-0.31	4.28	-0.76	0.69	83.11	1.16	17.25
28	PU-KU-99-21	56.65	0.94	-5.64	47.11	2.88	13.70	5.24	1.25	-0.08	83.66	1.18*	7.34
29	PU-KUG216	62.75	1.66	13.12	48.66	1.34	-0.83	5.25	-2.38	-0.16	85.33	0.98	12.12
30	PU-UPU-97-1	53.55	2.38	63.08	50.88	1.17	-0.58	5.83	-1.00	1.72	85	1.14	12.48
	General mean	56.03			48.29			5.51			83.74		
	SE ± m	4.19	1.29		1.68	0.42			0.59	0.42	1.88	0.16	

S. no.	Genotypes	NPP			NSP			PL			NCP		
1	AZAD-2	33.42	0.26	-3.29	6.27	-0.16	0.20	4.84	2.66	1.32	10.38	1.87	7.42
2	MASH- 114	34.42	1.92	-3.05	5.98	0.63	0.46	5.04	0.36	0.10	9.96	0.14	13.17
3	NU-1	35.45	-0.31	128.61	5.61	2.98	2.33	5.10	0.52	0.53	7.42	0.01	0.26
4	PU-07-7	30.58	1.26	4.52	5.81	-0.40	-0.11	4.30	1.61	0.19	6.47	2.59	0.18
5	PU-10	32.82	0.58	-2.43	6.28	0.33	-0.13	4.65	0.96	1.30	6.63	-0.18	0.65
6	PU-13-05	35.64	1.20	-3.06	6.79	-0.70	0.68	6.75	2.21	-0.14	8.63	-3.56	0.47
7	PU-15-2	42.99	0.08	-3.38	6.98	4.13	0.32	6.46	3.61	0.36	10.79	-0.91	1.16
8	PU-15-21	30.71	1.62	2.32	5.97	1.91	0.46	5.22	-1.89	0.61	9.32	0.74	12.62
9	PU-15-23	39.2	1.57	3.28	4.97	3.77	-0.11	4.07	1.99	-0.12	10.12	0.83	-0.347
10	PU-15-26	40.58	1.26	0.65	4.85	4.091	-0.13	5.04	1.77	-0.001	9.12	2.01	-0.12
11	PU-15-28	41.85	2.47	-2.08	5.98	-2.99	-0.14	5.96	-0.36	6.02	9.76	-2.72	-0.050
12	PU-15-29	36.78	0.30	26.49	4.77	3.34	0.28	4.31	2.17	3.14	8.18	4.05	3.33
13	PU-15-30	32.63	0.58	46.29	5.53	-0.59	0.72	4.17	-0.06	0.20	8.08	0.77	7.73
14	PU-15-31	36.4	0.04	-0.17	4.57	0.99	-0.01	4.32	-0.52	0.78	7.43	2.85	5.24
15	PU-15-32	36.65	1.17	16.12	4.81	-2.14	0.59	4.76	0.56	-0.05	8.50	0.11	-0.06
16	PU-15-34	36.3	1.49	2.06	6.06	0.89	-0.098	4.46	-0.06	0.89	6.61	2.99	0.51
17	PU-15-35	42.81	1.68	-1.21	3.74	2.11	-0.15	4.43	1.61	0.16	9.74	2.89	-0.32
18	PU-15-40	38.46	0.75	0.69	5.21	1.90	0.75	4.50	2.15	0.16	8.53	0.73	8.66
19	PU-17-4	37.22	1.45	95.56	4.49	3.43	0.14	4.97	0.59	-0.14	8.89	-0.70	2.57
20	PU-19	36.24	2.00	19.28	7.38	-0.90	0.04	6.1	1.03	0.27	10.54	0.95	9.19
21	PU-31	39.78	1.48	11.14	6.59	0.42	-0.14	6.21	2.94	0.02	9.06	-1.10	-0.34
22	PU-35	38.94	0.92	-2.69	5.25	3.13	-0.14	4.34	1.75	0.24	10.08	2.75	-0.06
23	PU-40	30.14	1.92	11.28	5.31	-2.09	0.29	4.53	-1.18	-0.14	8.35	-2.94	1.62
24	PU-7	36.72	1.39	9.28	4.88	1.82	2.28	4.44	2.53	0.15	8.8	2.55	2.62
25	PU-8	38.9	-0.60	-3.54	5.66	0.92	-0.14	4.67	4.00	1.26	10.02	0.19	8.79
26	PU-9	43.86	1.39	-1.12	6.70	2.99	1.95	5.99	0.06	0.19	11.26	0.86	0.50
27	PU-IPU-2-43	40.03	1.30	50.32	3.88	0.82	2.10	4.91	0.14	-0.13	6.18	2.11	5.97
28	PU-KU-99-21	32.11	0.44	12.15	6.14	1.51	-0.12	4.30	-0.33	0.52	10.93	3.31*	20.01
29	PU-KUG216	31.65	0.11	34.46	3.81	1.23	8.22	4.17	-0.09	0.88	10.5	4.89*	12.45
30	PU-UPU-97-1	28.53	0.14	15.81	4.82	-3.45	1.90	4.94	-0.78	0.83	10.88	1.81	5.59
	General mean	36.39			5.50			4.93			9.03		
	SE ± m	3.08	0.75		0.67	2.23		0.63	1.66		1.53	0.53	

		NPC			**1000 SW**			**SYP**		
1	AZAD-2	4.04	1.22	-0.11	47.60	2.20	19.42	6.50	1.73	-0.22
2	MASH- 114	4.26	4.06*	-0.12	40.56	-1.26	33.22	5.97	-0.37	9.01
3	NU-1	4.11	2.36	1.96	40.85	1.65	-5.90	4.12	1.06	-0.05
4	PU-07-7	3.24	1.81	-0.06	42.64	0.43	-8.45	5.22	1.10	0.02
5	PU-10	3.82	1.39	1.02	44.58	2.24	-8.48	6.21	0.59	-0.14
6	PU-13-05	5.67	1.25	0.36	41.27	2.06	4.58	8.15	1.64	3.43
7	PU-15-2	6.20	1.21	-0.12	42.70	3.10*	71.23	8.26	0.64	1.34
8	PU-15-21	3.77	0.33	1.57	35.54	-0.65	-3.26	4.20	2.47*	0.10
9	PU-15-23	3.68	-0.21	0.20	44.69	0.80	1.65	5.98	2.18	0.67

10	PU-15-26	3.83	0.65	-0.11	44.49	2.41	44.84	6.04	2.00	3.64
11	PU-15-28	5.41	1.10	-0.08	45.08	1.52	-3.36	6.49	-0.24	0.77
12	PU-15-29	4.74	0.68	0.45	43.01	0.29	-7.38	4.64	1.74	-0.07
13	PU-15-30	4.07	0.79	-0.12	42.18	0.11	-8.27	6.32	1.73	0.99
14	PU-15-31	3.78	0.59	-0.08	42.40	-0.46	-7.86	6.39	1.52	-0.04
15	PU-15-32	3.87	0.58	-0.12	43.86	0.79	-2.83	5.14	0.30	0.96
16	PU-15-34	4.24	1.88	-0.06	40.39	0.52	-1.11	5.88	2.48	0.06
17	PU-15-35	3.76	0.05	0.13	41.71	1.68	-8.37	6.40	2.19	2.29
18	PU-15-40	3.53	0.57	0.02	44.05	0.17	-7.47	5.57	-0.60	0.85
19	PU-17-4	3.34	0.16	0.34	42.92	0.14	-4.81	5.56	0.46	5.29
20	PU-19	4.28	1.89	1.00	42.57	1.58	-8.21	7.79	2.34*	0.25
21	PU-31	4.63	1.10	-0.12	42.38	1.12	-6.60	7.81	1.31	-0.21
22	PU-35	3.90	-0.04	1.91	43.67	1.32	-6.91	6.56	0.69	0.65
23	PU-40	3.17	0.09	-0.09	44.31	0.99	-8.36	6.11	0.91	0.16
24	PU-7	3.93	0.74	-0.12	48.48	2.65	17.65	5.95	-0.46	-0.21
25	PU-8	3.89	0.66	0.91	41.55	1.10	-8.51	7.13	2.07	-0.17
26	PU-9	4.54	0.64	1.34	43.55	4.67*	-8.26	6.12	0.75	-0.21
27	PU-IPU-2-43	4.07	1.53	-0.06	47.91	-4.55	65.86	5.74	1.44	0.46
28	PU-KU-99-21	3.28	0.17	0.96	49.47	0.55	-5.30	6.21	-0.51	1.97
29	PU-KUG216	3.59	0.85	-0.12	44.92	1.71	9.32	5.37	-1.91	-0.13
30	PU-UPU-97-1	3.93	1.76	0.20	41.79	1.00	32.55	5.28	0.67	0.31
	General mean	4.08			43.37			6.10		
	SE±m	0.50	0.57		2.66	.46		0.79	0.43	

Table 7: Estimation of stability parameters of different agro-morphological traits by Eberhart and Russell (1966).

= Mean, = Regression coefficient, = Deviation from regression ** and * indicates levels of significance at 5% and 1%, respectively.

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Figure 1: Graphs of stability for yield and attributing traits of Urdbean.

Table 7 illustrates the stability metrics for seed yield/plant and yield contributing characteristics, comprising mean (), regression coefficient (b_i), and deviation from linear regression (S^2d_i). A genotype with a high mean value, a unit regression coefficient ($b_i = 1$), and a dispersion not significantly different from zero (S^2d_i)deemed to be stable according to the [5]. A genotype with more than a unity regression coefficient is below in stability and adaptable to better-performing environments, conversely, genotypes with lower than one regression coefficient are above in stability and adaptable to weak environments. The following portion summarizes the stability parameters for eleven yield and yields contributing characteristics.

The most stable genotype for plant height was specified PU-7 as it had a higher mean (58.70) than the general mean (56.03) coupled with a regression coefficient closer to unity and non-significant deviation from regression ($S^2d_i = 0$) indicating wider adaptability across the environments (Table 7 and Figure 1). However, PU-13-05 and PU-15-21 bearing regression coefficient value more than unity was found to be less stable hence, can be adaptable to better-performing environments while genotype PU-KU-99-21 exhibited higher mean performance as compared to the general mean of the trait along with regression coefficient value lower than unity and non-significant deviation from regression ($S^2di = 0$) it indicated this genotype is suitable for poor environments. Similar results with respect to plant height were revealed by [20] and [12].

For the number of days to 50 percent flowering, genotype PU-35 was the most stable and early in flowering. It had a par mean value (49.11) with a general mean (48.29) coupled with a regression coefficient closer to unity and a non-significant deviation from the regression coefficient ($S^2d_i = 0$) indicating its wider adaptability over the environments. Genotypes namely *viz.,* PU-15-32, PU-15-35, PU-40, and PU-IPU-2-43 were bearing low values of mean with bi value more than unity and non-significant deviation from regression coefficient ($S^2di = 0$) were designated as the most stable genotypes in a favorable environment (Table 7 and Figure 1). Genotype PU-10 had a lower mean in the desired direction as compared to the grand mean paired with a regression coefficient approaching less than unity and a non-significant deviation from the linear regression coefficient indicating this genotype showed stable performance under unfavorable environmental conditions. [11] reported that genotypes of mungbean *i.e.* Pusa Vishal, SML668, IPM2057, PM2-14 and MH521 showed minimum mean value than population mean with regression coefficient approaches to unity and least non-significant deviation from regression coefficient (S^2di) and hence, showed poor adaptability in all the environments.

Genotype PU-15-2 was found stable for the number of branches per plant due to a higher mean value (7.87) as compared to the general mean (5.51) along with regression coefficient (b_i) close to unity and non-significant deviation from the regression coefficient. However, genotype PU-07-7 was bearing higher values with bi values more than unity and also showed non-significant deviation from regression ($S^2d_i = 0$) and was designated as the most stable genotype under favorable environments (Table 7 and Figure 1). Similarly, [17] and [22] reported stable black gram genotypes across the season and locations based on the mean, b_i and S^2di values. [11] while working on urdbean reported that nine genotypes (T9, Mash 114, Mash 479, IPU96-6, PL4158, PU19, SPS38, IPU96-16 and UH 82-14) for days to 50% flowering (DTF) and only one (PL4158) for days to maturity (DTM) showed lesser mean values than population mean with regression coefficient greater than unity (b-1) and least deviation mean value than population mean with non-significant regression coefficient less than unity and least S^2d_i and hence, recommended for unfavorable environment only. However, the genotype IPU96-6 exhibited lesser mean values than population mean with regression coefficient equal to unity (b = 1) with minimum deviation from regression coefficient and therefore, identified as stable genotype across the environment for days to maturity which is earlier in maturity value as compared to average mean value.

The number of days to maturity was consistent for genotypes namely *viz.,* PU-19, PU-35, PU-40, PU-15-26, and PU-15-32 due to their lower mean values except for PU-40 which showed at par mean value as compared to the population means, combined with regression coefficient that was nearer to unity and had the non-significant deviation from regression coefficient indicated wider adaptability across the environments (Table 7 and Figure 1). However, genotypes PU-13-05 and PU-8 were bearing low values of mean with bi value more than unity and non-significant deviation from regression coefficient ($S^2d_i = 0$) were designated as the most stable genotypes in favorable environments while genotypes PU-15-31 and PU-31 were bearing low values of mean with bi value less than unity and non-significant deviation from regression ($S^2d_i = 0$) were designated as the most stable genotypes in unfavorable environments. Previously, stable genotypes for days to maturity were reported by [9,22].

Genotype PU-35 was found stable for the number of pods per plant due to a higher mean value (38.94) as compared to the general mean value (36.39) along with a regression coefficient close to unity and non-significant deviation from regression ($S^2d_i = 0$) suitable for over the environments. However, genotypes PU-15-26, PU-15-32, and PU-IPU-2-43 were bearing higher mean performance as compared to the general mean with bi value more than unity and non-significant deviation from regression ($S^2d_i = 0$) and were designated as the most stable genotypes in favorable environments while PU-15-40 stable performed under unfavorable environments due its higher performance of mean with bi less than unity and non-significant S^2di (Table 7 and Figure 1). This result was further supported by [14,16,20].

Genotype PU-8 was found stable for the number of seeds per pod due to a higher mean value (5.66) as compared to the general mean (5.50) along with a regression coefficient close to unity and non-significant deviation from regression ($S^2d_i = 0$). However, genotype PU-15-34 performed stable under unfavorable environments due to higher mean performance with bi less than unity and non-significant S^2d_i value. Similar findings were observed by [2].

Genotype PU-19 was found stable for pod length due to its higher mean value (6.1) as compared to the general mean (4.93), regression coefficient close to unity, and non-significant deviation from regression (S^2di = 0). It indicated genotype PU-19 is stable over the environments. In the same way, similar findings in respect of pod length were earlier studied by [2].

PU-19 showed stable performance for the number of clusters per plant due to its higher mean value (10.54) as compared to the general mean (9.03) along with a regression coefficient close to unity and non-significant deviation from regression (S^2d_i = 0). Genotype PU-9 was stable in behavior under favorable environments due to non-significant S^2di with bi higher than unity and higher mean value as compared to the general mean (Table 7 and Figure 1) while PU-15-21 stable performed under unfavorable environments due to its higher mean value as compared to the general mean with regression coefficient less than unity and non-significant deviation from regression (S^2d_i = 0). Similar results were also obtained by [19,20].

PU-15-28 exhibited stable performance for the number of pods per plant due to its higher mean value (5.41) as compared to the general mean (4.08) with a regression coefficient close to unity and non-significant deviation from regression (S^2d_i = 0). PU-13-05 and PU-15-2 were stable in performance under favourable environments due to non-significant S^2d_i with bi values higher than unity and higher mean value as compared to the general mean (Table 7 and Figure1). This result was supported by [14,16].

Genotype PU-40 was found stable for 1000 seed weight due to its higher mean value (44.31) as compared to the general mean (43.37), close to unity and non-significant deviation from regression (S^2d_i = 0). However, genotype PU-35 showed higher mean performance, along with higher regression value and non-significant deviation from regression (S^2d_i = 0) was designated as the most stable genotype under favorable environments (Table and and Figure 1) while PU-15-23 and PU-15-32 showed stable performance under unfavorable environments due their higher performance of mean with bi less than unity and non-significant deviation from regression coefficient (S^2d_i = 0). Previously, stable genotypes for 1000 seed weight were reported by [11].

Genotype PU-40 performed a stable performance for seed yield per plant due to its higher mean value (6.11) as compared to the general mean (6.10) along with a regression coefficient close to unity and non-significant deviation from regression (S^2d_i = 0). However, genotype PU-31 showed higher mean performance, higher regression value, and non-significant deviation from regression (S^2d_i = 0) and was designated as the most stable genotype in favorable environments while PU-9 showed stable performance under unfavorable environments due to its higher performance of mean with bi less than unity and non-significant S^2di value (Table 7 and Figure 1). Similar outcomes in respect of seed yield per plant were confirmed by [14]. Similar results were reported by [11] in urdbean, and [12] in chickpea for days to 50% flowering, days to maturity and grain yield/plant.

Conclusions

- The present experiments were executed to investigate the extent of genetic diversity and to identify promising genotypes for further utilization in the breeding program of black gram.
- The experimental materials were composed of thirty black gram genotypes which were planted in Randomized Complete Block Design (RCBD) during *kharif* 2021 on three different dates of sowing under two locations. Data were recorded on agro-morphological traits from each environmental condition for traits like plant height, number of days to 50% flowering, number of branches per plant, number of days to maturity, number of pods per plant, number of seeds per pod, pod length, number of clusters per plant, number of pods per cluster, 1000 seed weight and seed yield per plant.
- Stability analysis was done and followed the Eberhart and Russell model,1966. Genotype PU40 was the most stable genotype across the environments for 1000 seed weight, days to maturity and seed yield/plant. However, genotype PU35 was most stable for days to 50% flowering, days to maturity and number of pods/plant. These genotypes could be utilized in future breeding programme for seed yield/plant improvement in urdbean and pyramiding of components traits such as number of pods/ plant, 1000 seed weight, days to 50% flowering, days to maturity and seed yield/plant.

Authors' Contribution

Conceptualization of research (RSK, SK); Designing of the experiments (RSK, SK); Contribution of experimental materials (RSK, SK, SCK); Analysis of data and interpretation (RSK, SK, SCK, SK, AKS, RP); Preparation of the manuscript (RSK, SK).

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