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Research Article

Interrelationship Between Emergence and Yield Parameters in Mung Bean: Implication for Selection

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Rapid and uniform seed germination and seedling emergence have been associated with grain yield under diverse environmental conditions. Twenty-one (21) mung bean accessions were evaluated at Ile-Ife and Kishi out-stations of the Institute of Agricultural Research and Training (IAR & T), Nigeria, to identify the emergence parameter(s) that could be selected for improvement of mung bean for yield. The experiment was laid out in a randomized complete block design (RCBD) in three replications. Data were collected on emergence and yield parameters and analysed using the Statistical Analysis Software (SAS). Mean, heritability, and correlation coefficient were estimated. Path coefficient analysis was used to partition correlations into direct and indirect effects using seed yield as the dependent variable. Heritability estimate was moderate to high for most of the traits. Accessions 3, 6, 14 and 15 with high pod and seed yield had also high values of coefficient of velocity of emergence (CVE) and emergence percentage (E%). All emergence parameters except emergence energy had significant correlation with yield traits. CVE and Emergence Index (EI) had strong positive correlation with number of seeds.pod^{-1} and pod yield. When only the emergence parameters were considered, CVE had highest direct effect (0.74) on seed yield followed by E% (-0.73) and EI (0.70). Total indirect effects of EI and CVE accounted for only 6.06% and 11.9% of the total correlation, respectively. It therefore suggests that EI and CVE are emergence parameters that could be selected for at early stage in improvement of mung bean for yield.

Keywords: mung bean, seed germination, seedling emergence, seed yield, correlation

1 Introduction

Mung bean (*Vigna radiata* (L.) Wilczek) belongs to the family Fabaceae, sub-family Papilionaceae and genus *Vigna*. Mung bean has been reported to be rich in vitamins, particularly thiamine, riboflavin, and niacin (Luo et al., 2016; Lim, 2012), and other phytochemicals such as alkaloids, flavonoids, saponins, phenols and bioactive peptides which exhibit an array of pharmaceutically important properties (Mehta et al., 2021).

It is important that seeds have high physical, genetic, and physiological characteristics, as this will ensure uniform emergence and crop establishment, which guarantee good agronomic performance leading to good crop yield (Marcos-Filho, 2015). Rapid, consistent and uniform seed germination and seedling emergence under diverse environmental conditions is a desirable attribute for seedling growth and, ultimately, grain yield in various food crops including legumes (De Ron et al., 2016). Crop species vary widely in how fast their seeds germinate, the rate of emergence being the result of the interaction between the crop genotype and specific environment (Schmuths et al., 2006). The time taken to complete the germination process is one of the important parameters of seed quality (Dutt & Geneve, 2007). The coefficient of velocity of emergence (CVE) analyses the rapidity of germination and its value rises as the number of germinated seeds increases and time required for germination decreases (Sobarzo-Bernal et al., 2021).

Some researchers have reported relationship between emergence parameters and yield. Hampton and Tekrony (1995) reported that one of the tools for measuring good plant density and yield is the germination percentage and seedling emergence index. Emergence percentage

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(E%), emergence index (EI), and emergence rate index (ERI) have been reported as essential components of seedling vigour and grain yield (Kader, 2005). Ige et al. (2021) conducted a study to assess genetic variation and heritability of seedling emergence traits, and association with grain yield characteristics. They reported that higher seedling emergence percentage is required for greater grain yield. Fayeun et al. (2016) reported that the genetic variation existing among the seedling emergence traits, percentage heritability, and the correlation that exist among them are vital tools that are needed for effective selection for grain yield in maize. Opeke and Fakorede (1986) observed that selection for high emergence traits resulted in a positive gain in maize grain yield.

Studying the correlation between and among traits is crucial to determine how selection for secondary traits affects a primary trait (Umar et al., 2010). Studies on relationship between emergence parameters and grain yield of crops abound in the literature but it is very limited in mung bean. Therefore, the objective of this study is to determine the relationship between emergence parameters and seed yield in mung bean, and to determine the emergence traits that could be used as selection criteria for yield in a mung bean improvement program.

2 Materials and Methods

2.1 Experimental Design and Management Practices

Twenty-one accessions of mung bean were evaluated in the early and late cropping season of 2021 at the Ile-Ife (Rainforest) and only in the early season at Kishi (Savannah) out-stations of the Institute of Agricultural Research and Training (IAR&T), Nigeria. The experimental design was a randomized complete block with three replicates. The plot size was 2.4 × 2.4 m with a spacing of 0.6 m between rows and 0.6 m within rows to obtain a plant population of 50 plants.plot^{-1}. Manual weeding was carried out on the field as necessary. Field insect pests were controlled using Magic Force (Lambdacyhalothrin 15% + Dimethoate 300 g.l^{-1}).

2.2 Data Collection

Data were collected on emergence count at 5, 7, and 9 days after sowing, from which other emergence parameters were estimated. Ten pods were selected randomly within plots, threshed, and the average of the seeds was recorded as number of seeds.pod^{-1}. Number of pods. plants^{-1} was estimated by dividing the total number of pods per plot by number of plant stand per plot at harvest, pod yield was taken as the weight of the total pods harvested per plot in kg.plot^{-1}. All the pods per plot were threshed, chaff removed and the seeds weighed. This was recorded as seed yield in kg.plot^{-1}. One thousand seeds were randomly picked per plot and the weight recorded as 1,000 seed weight in gramme (g).

Emergence percentage (E%) was estimated as number of plants that emerged in day 9 expressed as percentage of the number of seeds sown according to Fakorede and Ojo (1983). Emergence index (EI) was estimated according to the Association of Official Seed Analysis (1983). Emergence rate (ER) was estimated according to Ellis et al. (1985) as:

$$ER = \sum n / \sum D \qquad (1)$$

where: n – number of seeds germinated in a day; D – no. of days from start of the test

Emergence rate index (ERI) was estimated according to Fakorede and Ojo (1983). Coefficient of Velocity of Emergence (CVE) was estimated according to Kader (2005). Emergence energy (EE%) was estimated in percentage as described by Ruan et al. (2002) as:

$$\frac{\textit{number of germinated seeds at 5 days after sowing} \times 100}{} \qquad (2)$$

Total number of seeds sown.

2.3 Data Analyses

Data were analysed using SAS. Means, standard error (SE), coefficient of variation (CV), and range were estimated for each parameter. Combined analysis of variance was conducted and broad-sense heritability (BSH) was estimated from variance components. Correlation analysis was also conducted. Path coefficient analysis was used to partition correlation into direct and indirect effects using seed yield as the dependent variable. The sum of direct and indirect effect of each trait gave the total correlation.

3 Results and Discussion

3.1 Mean Performance of the Mung Bean Samples for Yield Traits

Some of the mung bean samples had good yield performance (Table 1). Accession 6 had the highest seed yield.plot^{-1} (0.94 kg.plot^{-1}) followed by accession 14, 15, 3, and 7. These accessions also had high number of pods.plant^{-1} and high pod yield. Accession 18 had highest 1,000 seed weight (44 g) followed by Accession 7 (42 g). This weight is lower than the mean (50.9 g) reported by Kamil (2017). This is likely due to the genotypic variation in seed size. The wide range observed for the yield and emergence parameters indicates wide variability among the mung bean samples. Broad-sense heritability (BSH) was high for number of seeds per pod (92%,) but moderate for seed and pod yield (16–17%) in this study. This result is in line with the report of Zaid et al. (2012) who reported moderate heritability estimates for number of seeds per pod. The moderate to high heritability estimates for these traits indicate that the traits are under genetic control and could easily be improved through selection (Yoseph et al., 2022).

3.2 *Mean Performance of the Mung Bean Samples for Emergence Parameters*

Emergence percentage (E%) was highest in accession 8 (45%) followed by accession 14 with 44% (Table 2). Accession 14 had the highest CVE (101.93) followed by accession 2 (101.67) and 8 (101.63). However, despite the high values of CVE and E% for accession 8, the yield was low. This may be due to some other factors such as pod length and width of the accession or other environmental factors. Kamrul et al. (2018) reported that salinity causes delay and reduction in germination percentage of mung bean. CVE also diminishes under salt stress.

Accessions 3, 6, 14, and 15 had high seed and pod yield. These accessions also had high values of CVE with E% ranging between 30–40%. This is an indication that plants that emerge quickly and uniformly tend to have good yield. Emergence energy (EE) was highest in accession 15 (32%) followed by accession 2 (30.3%) which also had high emergence percentage (42%). Willan (1987) defined EE, also referred to as germination energy (GE), as percentage by number of seeds in a given sample which germinate within a definite time under optimum or given conditions. Therefore, accessions with high EE values are generally considered to have better vigour and potential

Table 1 Mean ± S.E, CV, range and broad-sense heritability (BSH) estimates of yield traits for the mung bean samples

Accessions	Pods.plant^{-1}	Seeds.pod^{-1}	1,000 seed weight (g)	Pod yield (kg.plot^{-1})	Seed yield (kg.plot^{-1})
1	33.10	12.31	42.46	0.66	0.26
2	22.55	13.00	39.48	1.02	0.53
3	34.54	13.47	39.22	1.05	0.74
4	38.58	13.60	40.36	1.10	0.60
5	12.20	12.94	38.35	0.72	0.48
6	24.36	13.00	39.98	1.49	0.94
7	33.61	12.20	42.28	1.10	0.69
8	39.30	12.90	39.32	0.68	0.39
9	24.88	11.90	42.02	0.54	0.47
10	24.04	7.23	40.55	0.14	0.08
11	21.95	13.59	38.99	0.82	0.48
12	18.45	13.07	37.73	0.94	0.57
13	25.75	12.43	40.09	0.58	0.34
14	30.16	13.20	37.31	1.22	0.88
15	18.44	13.10	40.56	1.36	0.88
16	20.81	12.99	41.37	0.94	0.63
17	25.37	12.20	43.44	0.68	0.36
18	24.05	12.70	44.61	0.64	0.43
19	25.49	7.30	38.76	0.45	0.20
20	31.00	11.59	41.76	0.97	0.56
21	40.03	7.46	37.02	0.26	0.15
Mean	27.04	12.09	40.28	0.83	0.51
S.E	1.93	0.21	0.36	0.09	0.05
CV (%)	73.92	11.89	8.51	81.08	78.18
Range	1–110	6–17.6	29- 51.9	0– 4.69	0 – 3.13
BSH (%) ±S.E	-22.20 ±0.41	92.0 ±0.33	-27.08 ±0.42	17.93 ±0.36	16.40 ±0.37

S.E – standard error; CV – coefficient of variation for high yield, as they are better able to overcome environmental stresses and establish themselves quickly in the field.

BSH was high for E% (32.5%), ER (49.4%), and ERI (43.4%), moderate for EI (16.5%) and CVE (20%), but negative for EE. The low heritability estimates for EE showed that the parameter is greatly influenced by environment.

3.3 Correlation Between Emergence and Yield Parameters for the Mung Bean Samples

Significant positive correlation exists among almost all the yield parameters (Table 3). This is similar to the result obtained by Singh et al. (2021) on mung bean. Strong positive correlation exists between seed and pod yield (0.99**). This means an increase in pod yield will lead to corresponding increase in seed yield. Number of pods per plant was negatively correlated with ER (-0.2*). The strong positive correlation observed between number of seeds.pod^{-1} and EI, number of seeds.pod^{-1} and CVE, pod yield and CVE, and pod yield and EI revealed the importance of the two emergence parameters to yield in mung bean. Bojana et al. (2018) also reported positive correlation between EI and grain yield in maize. This implies that accessions with high EI and CVE could be selected in quest of breeding mung bean for high grain yield. 1,000 seed weight only had significant correlation with ERI.

Highly significant positive correlation also existed among the emergence parameter except with EE. Positive correlation exists between E% and ER, E% and EI, as well as between CVE and ER. This is in contrary to the report of Manasa et al. (2023) who reported negative correlation among these traits under cold stress.

Table 2 Mean ± S.E, CV, range and broad-sense heritability of emergence parameters for the mung bean samples

Accessions	Emergence %	Emergence index (days)	Emergence rate index (days)	Emergence energy (%)	Emergence rate (days)	Coefficient of velocity of emergence (%)
1	25.00	3.27	0.13	24.67	1.30	38.27
2	42.00	5.07	0.13	30.33	2.41	103.67
3	37.33	4.45	0.14	21.33	2.23	90.33
4	41.00	4.48	0.12	24.00	2.20	100.03
5	37.00	4.39	0.12	20.67	2.19	95.32
6	29.33	3.76	0.13	24.33	2.04	62.99
7	25.67	3.23	0.14	18.00	1.80	61.69
8	45.00	4.38	0.13	19.00	1.86	103.63
9	41.67	4.30	0.13	15.75	2.14	91.58
10	19.60	2.56	0.15	15.00	1.56	39.18
11	35.20	4.66	0.14	23.50	2.08	80.18
12	31.33	3.89	0.12	25.67	2.16	76.41
13	33.00	3.97	0.13	25.67	1.61	56.47
14	44.00	4.84	0.13	24.67	2.28	106.93
15	33.00	4.58	0.13	32.33	2.34	92.11
16	35.33	3.97	0.12	23.00	2.12	78.82
17	35.67	3.73	0.12	17.33	2.09	87.84
18	30.40	3.80	0.12	24.00	1.78	53.58
19	34.00	3.74	0.18	16.33	1.61	68.69
20	42.33	4.39	0.12	22.33	2.17	97.99
21	20.00	3.13	0.15	19.33	1.41	49.64
Mean	34.25	4.03	0.13	22.17	1.97	78.2
S.E	1.34	0.17	0.004	1.07	0.05	6.15
CV (%)	32.3	30	13.52	44.81	31.37	48.7
Range	002 -62	0.25–9.08	0.07–0.22	002 -66	0.2–3.6	0.32–320.5
BSH (%) ±S.E	32.48 ±0.23	16.48 ±0.36	43.35 ±0.23	-45.7 ±0.45	49.42 ±0.33	20.01 ±0.36

S.E. – standard error; CV – coefficient of variation, BSH – broad-sense heritability (%)

Table 3 Correlation coefficients of emergence and yield parameters for the mung bean accessions

Parameters	Seed yield (kg.plot^{-1})	Pod.plant^{-1}	Seeds.pod^{-1}	1,000 seed weight (g)	pod yield (kg.plot^{-1})	E%	EI (days)	ERI (days)	EE (%)	ER (days)	CVE (%)
Seed yield (kg.plot^{-1})	1.00	0.57**	0.56**	0.21*	0.99**	0.49**	0.66**	0.51**	0.06	0.38**	0.66**
Pod.plant^{-1}		1.00	0.19*	0.21*	0.57**	0.06	0.35**	0.62**	-0.10	-0.20*	0.25**
Seeds.pod^{-1}			1.00	0.18	0.57**	0.51**	0.63**	0.48**	0.08	0.39**	0.61**
1,000 seed weight (g)				1.00	0.21*	0.01	0.09	0.20*	-0.04	0.04	0.09
Pod yield (kg.plot^{-1})					1.00	0.51**	0.67**	0.50**	0.06	0.41**	0.68**
E%						1.00	0.84**	0.26**	0.17	0.73**	0.86**
EI (days)							1.00	0.71**	0.20*	0.52**	0.97**
ERI (days)								1.00	0.09	0.01	0.60**
EE (%)									1.00	0.20*	0.24**
ER (days)										1.00	0.60**
CVE (%)s											1.00

E% – emergence percentage; ERI – emergence rate index; EI – emergence index; CVE – coefficient of velocity of emergence; EE – emergence energy (%); ER – emergence rate; * – significant at $P < 0.05$; ** – significant at $P < 0.01$

Table 4 Path coefficient analysis showing direct (bold on diagonal) and indirect (off diagonal) effects of emergence and yield parameters on seed yield for the mung bean accessions

	Parameters	1	2	3	4	5	6	7	8	9	10	C	I
1	**Pod.plant^{-1}**	-0.068	-0.003	0.001	0.638	-0.003	0.070	0.008	-0.002	0.006	-0.044	0.601	0.669
2	**Seeds.pod^{-1}**	-0.019	-0.011	0.001	0.585	-0.021	0.130	0.007	0.001	-0.008	-0.107	0.557	0.568
3	**1.000 seed weight (g)**	-0.017	-0.002	0.003	0.221	0.000	0.020	0.003	-0.001	-0.001	-0.017	0.210	0.207
4	**Pod yield (kg.plot^{-1})**	-0.041	-0.006	0.001	1.000	-0.022	0.135	0.006	0.000	-0.011	-0.118	0.943	-0.057
5	**E%**	-0.005	-0.005	0.000	0.529	-0.043	0.168	0.003	0.002	-0.022	-0.148	0.479	0.522
6	**EI (days)**	-0.024	-0.007	0.000	0.707	-0.036	0.199	0.009	0.003	-0.017	-0.168	0.667	0.468
7	**ERI (days)**	-0.042	-0.006	0.001	0.528	-0.011	0.138	0.013	0.001	-0.002	-0.101	0.519	0.506
8	**EE (%)**	0.009	-0.001	0.000	0.017	-0.006	0.039	0.001	0.016	-0.007	-0.044	0.024	0.007
9	**ER (days)**	0.013	-0.003	0.000	0.390	-0.031	0.110	0.001	0.004	-0.031	-0.105	0.348	0.379
10	**CVE (%)**	-0.017	-0.007	0.000	0.718	-0.037	0.194	0.007	0.004	-0.019	-0.172	0.672	0.844

% – emergence percentage; ERI – emergence rate index; EI – emergence index; CVE – coefficient of velocity of emergence; EE – emergence energy (%); ER – emergence rate; C – total correlation: I – total indirect effect

Table 5 Path coefficient analysis showing direct (bold on diagonal) and indirect (off diagonal) effects of emergence parameters alone on seed yield of the mung bean accessions

Parameters	E (%)	EI (days)	ERI (days)	EE (%)	ER (days)	CVE (%)	C	I
Emergence percentage (E%)	-0.73	0.59	-0.06	-0.03	0.07	0.63	0.48	1.20
Emergence index (EI) (days)	-0.61	0.70	-0.17	-0.05	0.06	0.72	0.66	-0.04
Emergence rate index (ERI) (days)	-0.18	0.49	-0.24	-0.01	0.003	0.44	0.50	0.74
Emergence energy (EE) (%)	-0.11	0.15	-0.02	-0.21	0.02	0.21	0.04	0.25
Emergence rate (ER) (days)	-0.51	0.37	-0.01	-0.05	0.11	0.44	0.36	0.25
Coefficient of velocity of emergence (CVE) (%)	-0.62	0.68	-0.14	-0.06	0.06	0.74	0.67	-0.08

C – total correlation; I – total indirect effect

3.4 Contribution of Emergence and Yield Parameters to Seed Yield in the Mung Bean Accessions

When the correlations were partitioned into direct and indirect effect using path analysis (Table 4), pod yield had highest positive direct effect on seed yield (1.0) followed by EI (0.199). This result corroborates the findings of Agbeleye et al. (2020) and Itefa et al. (2014). Pod.plant^{-1}, seed.pod^{-1}, E%, ER, and CVE had negative direct effects on seed yield, while other parameters had positive direct effect. CVE had highest negative direct effect (-0.172) on seed yield. All the traits had high indirect effect on seed yield through pod yield.

When only the emergence parameters were considered (Table 5), CVE had highest direct effect (0.74) on seed yield followed by E% (-0.73) and EI (0.70). Total indirect effects of EI and CVE accounted for only 6.06% and 11.9% of the total correlation, respectively. Asiedu et al. (2012) also stated that a treatment on seeds with highest CVE is considered to be a better treatment with a better effect on germination. This shows that CVE and EI are the most important emergence parameters for seed yield in this study. It therefore means that direct selection of accessions with high values of these emergence parameters may be done at early stage and utilized to enhance mung bean yield.

4 Conclusions

Rapid progress would be made in an improvement program if selection could be made at seedling stage of crops. This study revealed that Accessions 3, 6, 14, and 15 are promising mung bean samples for cultivation and breeding purposes in the study ecologies. Coefficient of velocity of emergence (CVE) places emphasis on the time required for reaching final percentage of emergence. Even though the use of CVE in selecting for yield has been argued in some reports, emergence index (EI) and coefficient of velocity of emergence (CVE) contributed significantly to yield in the mung bean samples among emergence parameters. However, efficiency of CVE in selecting for yield still needs to be further studied to establish its significance. Although emergence energy (EE) values indicate potential for high yield, it did not seem to play a significant role in yield of the mung bean samples studied.

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