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GENOTYPE-ENVIRONMENT INTERACTION STUDY OF SEEDS HARVESTED PER PLANT IN MUNG BEAN (*Vigna radiata* (L.) WILCZEK) LINES GROWN IN TWO AGRO-CLIMATIC ZONES OF BURKINA FASO USING GGE-BIPLOT ANALYSIS

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ABSTRACT: The objective of this study was to evaluate the adaptability of mung bean lines introduced in Burkina Faso and to identify favorable environments for its cultivation. The present study was thus conducted on forty-four mung bean (Vigna radiata) genotypes in two agro-climatic zones of the country, namely the Sahelian zone and the Sudano-Sahelian zone. The experiments were more specifically conducted in three environments of these two agro-climatic zones characterized by an unequal spatio-temporal distribution of rainfall: Pobé, Kamboinsé and Saria. The field trials were conducted during the rainy season using an augmented bloc design with one check. Seeds harvested per plant weight as yield related important trait where recorded and analyzed. The results show that seed yield per plant varied with regards to the environments and to the genotypes. Indeed, the combined analysis of variance revealed the presence of a significant variability and an important influence of the environmental component in this variability. Also, using GGE-biplot analysis, study revealed that the most favorable environments during this mung bean multi-location trial in Burkina Faso where Kamboinsé and Pobé. These are the sites where the best performance in terms of seeds harvested per plant was recorded. GGE-biplot analysis also allowed to identify genotypes that shows specific adaptation to Kamboinsé and to Pobé. These are the genotypes: V 2709; VC 1481A/VC 1560A; NM 94 and 9154 for Pobé in the Sahelian zone, the most arid environment, and genotypes PLM 944; KPS2; Kyungkijaerae 16 and VC 1168D/VC1560A for Kamboinsé a relatively more humid zone.

KEYWORDS: Mungbean (Vigna radiata), Genotypes Environment Interaction, GGE-biplot, Multi location trial, Burkina Faso.

1 INTRODUCTION

Mungbean [*Vigna radiata* (L.) Wilczek] is an important annual, self-pollinating, widely distributed grain legume. It is cultivated throughout Asia, Australia, the West Indies, South and North America, tropical and subtropical Africa. And according to [1], on account of its short duration, photo insensitivity, and dense crop canopy, it assumes special significance in crop intensification, diversification, and conservation of natural resources and sustainability of production systems. In Burkina Faso its cultivation is in its infancy, which makes it a minor crop. Recently, fifty (50) accessions have been introduced in Burkina Faso and characterized and out of these 50 genotypes, 44 performed well at Kamboinsé However, plants have generally shown variations in their response to environmental changes. Therefore, according to [2], the cultivation of genotypes in various environments can be used as a tool to identify the highest yielding and most stable genotypes. Thus, as reported by [3], the selection of climatic stresses resistant lines is crucial for proper introduction into the country's cropping system and for further work, it is necessary to study the performance of all these mung bean lines in different locations of the country. Also, GGE (Genotype and Genotype-by-Environment) biplot a methodology to have a visual analysis of the Genotype (G) by Environment (E) interaction pattern of multi-environment trial data were suggested by [4] and [5] So, the present study reports a genotype-environment interaction (GEI) study using GGE biplot analysis in order to identify mungbean stable lines and best environments for further studies on this orphan legume in Burkina Faso.

2 Material And Method

2.1 Experimentation Sites

The experimentations were conducted in Burkina Faso under rainfed conditions during 2018 cropping season in three Locations distributed in two agro-climatiques zones: Kamboinsé and Saria located in Soudano-Sahelian zone and which registered a rainfall of respectively 833.5 mm and 879.5mm while Pobé in the driest part of the country, the Sahelian Zone received a rainfall of 594.3 mm (Table 1).

Table 1. Location and rainfall data of experimental sites

Sites	Rainfall (mm)	Planting date	Latitude	Longitude	Altitude (m)
Saria	879.5	25/07/2018	12° 16 N	2° 9 W	488
Kamboinsé	833.9	25/07/2018	12 ˚ 27 N	1˚ 32 W	296
Pobé	594.3	21/07/2018	13°58 N	1°44 W	334

2.2 Plant Material And Experimental Design

Forty-four (44), mung bean lines imported from the Australian Genebank were used in this study. For each location involved in this experimentation, lines were planted following an augmented block design in three blocks as described by [6], using a cowpea variety as a check crop. Each genotype in each environment was randomly assigned and planted in a single row of 03 m long, keeping inter-row and intra-row spacing of 50 cm and 60 cm respectively. Each experimental plot received all management practices equally and appropriately according to the recommendations for mung bean cultivation. At maturity, seed were harvested per plant on each line in each location weighted and analyzed.

2.3 Data Analysis

Data from all locations were pooled and tested for the presence of significant G×E by using combined analysis of variance. In order evaluate the stability and adaptability of genotype and also suitability of environment, GGE biplot analysis was performed, considering the simplified model for two main components. [7] reported that GGE analysis partitions G + GE into principal components through singular value decomposition of environmentally centered yield data. The Analysis of pulled variance and GGE Biplot were carried out using the GenStat version 12 [8].

3 Results And Discussions

3.1 Results

Seeds harvested per plant during these multi-location trials, on each accession in each location as well as the average value of total seeds harvested in each location are reported in table 2.

Table 2. Mung bean line seed harvested per plant weight and means per location

GENOTYPES	Seeds harvested/pl (gr)			
	Kamboinsé	Saria	Pobé	Mean/accession
22	44.2	3.65	15.47	21.11
9154	31.1	6.87	65.33	34.43
13584	10.5	1.37	17.2	9.69
13644	32.97	3.35	0	12.11
13674	18.04	6.08	33.38	19.17
CES 1d-21/PHLV 18	39.57	4.72	19.9	21.4
Chunbukjaerae 2	14.71	0.45	0	5.05
Chunbukjaerae 7	29.63	14.15	27.8	23.86
CO 1	14.3	6.27	32.65	17.74
CPI 29755	25.3	11.23	0	12.18
CPI 32968	22.91	3.73	6.65	11.1
DAU XANH	31.44	11.3	16.6	19.78
Emerald	35.91	3.04	4.3	14.42
EWVN	19.17	0	4.32	7.83
IBS 3317	26.24	3.82	31.6	20.55
King	29.19	13.77	35.83	26.26
KPS1	14.47	12.03	7.15	11.22
KPS2	49.26	6.28	37.48	31.01
Kyungkijaerae 16	50.99	12.1	26.9	30
M 9	37.09	6.36	26.55	23.33
NM 92	29.39	4.5	15.64	16.51
NM 94	28.87	15.12	54	32.66
PLM 944	45.77	14.35	0	20.04
Q14723	30.27	8.93	13.1	17.43
Q14724	35.2	0.3	24.8	20.1
Q14725	22.23	4.33	0	8.85
Q14726	27.84	4.02	30.72	20.86
Q14728	43.2	4.6	26	24.6
Q14729	18.11	9.45	6.4	11.32
Q14732	23.23	10.92	21.53	18.56
Satin	38.09	5.02	12.6	18.57
Shanhua 1/VC1163A	30.5	3.15	10.18	14.61
Shantung	45.53	5.1	2.78	17.8
V 2709	40.73	7.7	43.57	30.67
V 2802	22.51	10.67	5.34	12.84
VC 1131A/VC 1163B	20.04	6.46	10.88	12.46
VC 1168D/VC1560A	70.9	7.5	26.26	34.89
VC 1177B/VC 1647 A	14.35	3.5	35.7	17.85
VC 1301 /PHLV 18	14.43	7.5	19.76	13.9
VC 1481A/VC 1560A	25.13	8.25	46.93	26.77
VC 1560 C /VC 1628 A	36.17	3.06	13.83	17.69
VC 2764A/VC 3826	30.74	7.5	29.04	22.43
VC6372 (45-8-1)	20.16	1.05	7.32	9.51
White gold	31.38	0.3	36.95	22.88
Min	10.5	0	0	5.05
Max	70.9	15.12	65. 33	34.89
Means	30.04	6.45	20.51	19

3.1.1 DESCRIPTIVE STATISTICS OF SEED HARVESTED PER PLANT DURING THE MULTILOCATION TRIAL

The average value of mung bean seeds harvested per plant varied from one site to another as it can be seen on Table 2. Thus, the lowest average value was observed in Saria with 6.45g/pl while the highest average values, observed in Kamboinse and Pobé where respectively 30.04g and 20.51g. The highest value of this trait was 70.9g seeds per plant and was recorded on genotype VC1168D/VC1560A in Kamboinsé. Apart from the fact that some accessions did not produce in Saria and Pobé, the lowest weight of harvested seeds per plant (0.3gr), was recorded in Saria on the genotypes Q14724 and White Gold. In two locations out of the three. some genotypes did not produce. These are the sites of Saria with genotype EWVN and Pobé where five genotypes out of 44 did not produce: namely: CPI 29755; Chunbukjaerae 2; 13644; PLM 944 and Q14725. Overall, the least favorable environment seems to be Saria where the lowest values of the studied trait were recorded. Box plot in Figure 1 is an illustration of the relative performance of the different accessions in each site. It shows that. Kamboinsé has the highest average yield (30.04 g/pl) followed by Pobé (20.51 g/pl) and then comes Saria with an average value of 6.45 g/pl. So. Saria appears to have been the least favorable out of the three experimental sites (fig1).

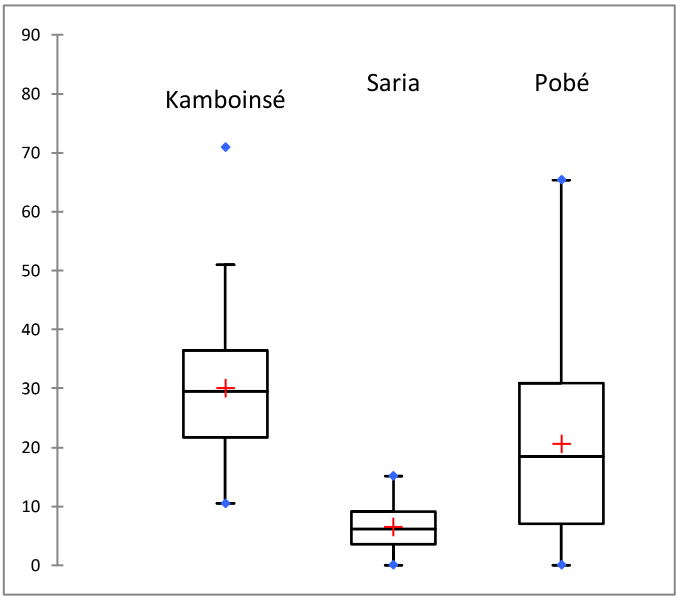

Fig. 1. Box-plot showing variation of seeds per plant in each location

3.1.2 ANALYSIS OF VARIANCE FOR SEEDS HARVESTED PER PLANT

Table 3 presents the result of the combined analysis of variance (ANOVA) for seeds harvested per plant. The ANOVA were highly significant (P<0.001) for the genotype. site (environment) and significant for the genotype-environment interactions (GEI). However, regarding the contribution of each factor to the expression of the seeds harvested per plant, it appears that the highest contribution is due to the genotype with 61.43% then the GEI with 29.41% and finally the effect of the environment which has the lowest contribution with 6.55%.

Table 3. Results of analysis of variance for seeds harvested per plant on mungbean lines

Source de variation	d. f.	SS	m. s.	F pr.	% ss
Genotypes	44	74207.4	1686.5***	<0.001	**61.43**
Sites	2	7241.7	3620.8***	<0.001	**6.55**
Genotypes x Sites	88	35538.1	403.8**	0.006	**29.41**
residuelle	24	3811.5	158.8		2.61
Total	158	120798.6	764.5		-

3.1.3 ENVIRONMENTAL STABILITY STUDY USING GGE BIPLOT MODEL

Figure 2 is a graphic displaying a vectorial view of the environments following a GGE-biplot analysis. Vectors represented in this figure are called environmental vectors and were used in this study to identify the best environments for selecting the best mungbean genotypes. This selection is based on the genotype's discrimination capacity by the different locations or environments. Also, according to [9], a long environment vector reveals a strong capacity to discriminate genotypes and the cosine of the angle between two environments sheds light on the correlation between them. Based on this, results shows that the principal components 1 and 2 (PC1 and PC2) of the biplot (fig2) represents respectively 61.67% and 34.38% of the genotype and genotype-by-environment interaction (GGE) for a total of 96.05% to the total variation. Also, the lines that connect the experimental sites (environments) to the origin of this biplot called environmental vectors. So. regarding to the angle formed by the different environmental vectors in our study. two groups of environments can be distinguished: the first one is Pobé and Saria, which seem to be correlated because of the acute angle between the vectors of the two sites. the second group being Kamboinsé. However, out of the three environments, the longest vector since the origin was observed respectively for the Pobé site, followed by Kamboinsé and finally Saria, for studied trait. Inconsequence, Pobe and Kamboinsé are the most discriminating environments of the three experimental sites. Saria, whose vector is the shortest from the origin, is a less discriminating and less productive environment. So, Pobé and Kamboinsé could be considered at this stage as the best environments for the selection of specifically adapted genotypes with high yields in terms of seeds harvested per plant

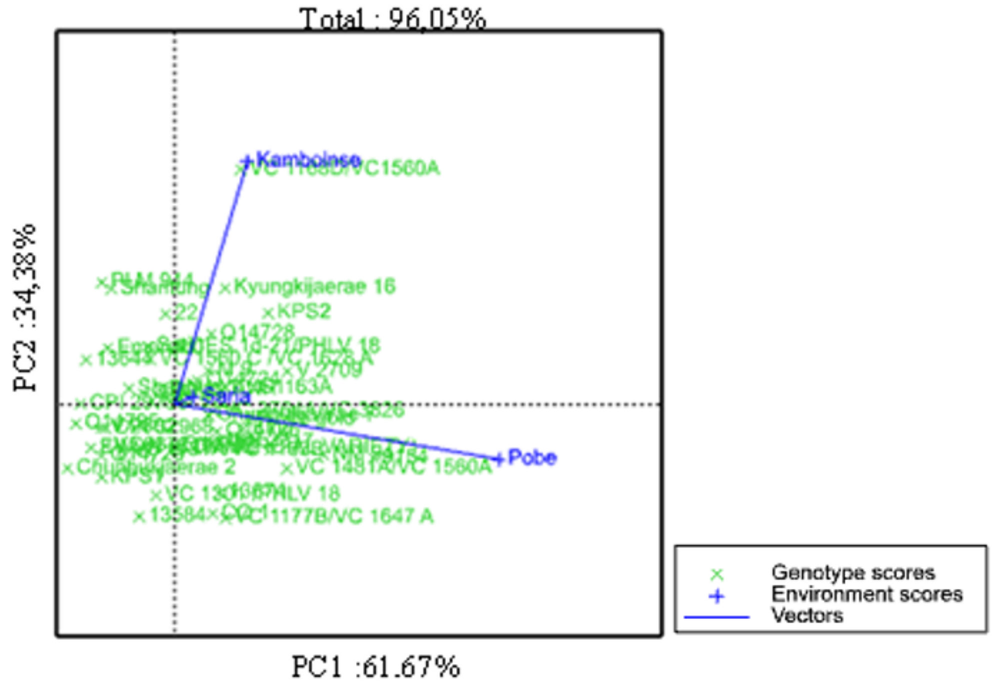

Fig. 2. ***GGE biplot showing 44 mung bean accessions in three different environments and their corresponding environmental vectors***

3.1.4 IDENTIFICATION OF STABLE GENOTYPES USING THE GGE-BIPLOT PROJECTION

The GGE dual projection has the ability to identify stable genotypes across different determining environments. Thus, the polygon in Figure 3 is formed by connecting the genotypes furthest from the origin of the double projection graph so that all remaining genotypes are contained within the polygon. In our study, in terms of seeds harvested per plant, the analysis of this double projection showed a polygon divided into six vertices. The best but also the worst performing genotypes (VC1168D/VC1560A; 9154; VC1177B/VC1647; 13584; Chunbukjaereae2 and PLM944) are located on the vertices of the polygon. According to [10] genotypes located on the polygon vertices performed best or worst in one or more environments. Indeed, among the accessions located at the polygon peaks, there are accessions that have recorded the worst performance, therefore, linked to no test site. These genotypes seem to be poorly adapted to the three experimental sites. These are genotypes Chunbukjaerae2 and 13584.

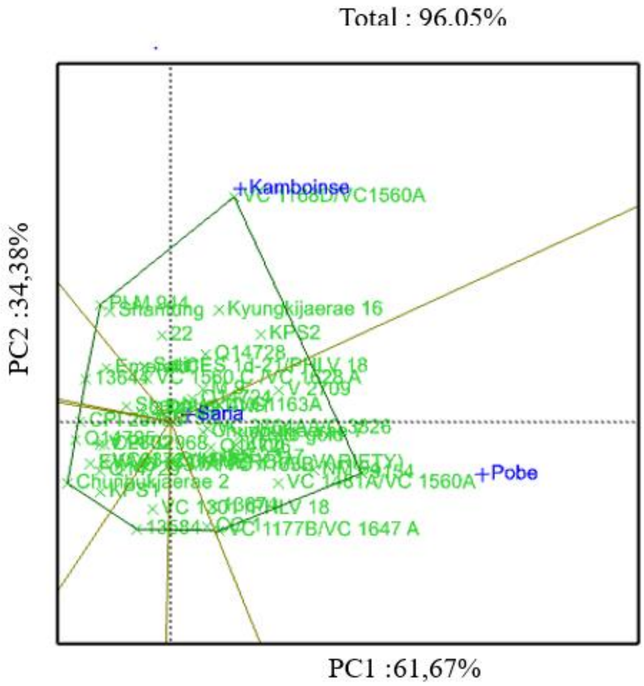

Fig. 3. Polygonal view of the GGE biplot for stable accessions for grain yield per plant

3.2 DISCUSSION

seeds harvested per plant evaluation as important yield related trait is justified in this study because of its strong and positive correlation with the other important components of yield [11]. So, based on this trait. the performance of the different lines observed in this study revealed significant difference among experimental sites in addition to those between lines following combined analysis of variance. Our results corroborate those of [12], [13] and confirm the presence of environmental influence on this important yield related trait [14]. Thus, while the highest averages were observed at the Kamboinsé and Pobé sites, very low values of seed harvested per plant were observed at Saria. Also, a highly significant differences between genotypes, locations and for genotype-by-environment-interactions were confirmed by analysis of variance. This indicates the presence of genetic variability between genotypes as well as between environments (experimental sites) for seeds harvested per plant. However, the largest contribution to this variability is due to genotypes with 61. 43% of the total variability. Locations (environments) and genotype-by-environment interactions together contribute 35.96% of the total variability. This contribution, although comparatively small, is significant and explain why the performance of the different genotypes varied from one experimental site to another. The significant contributions of the factors "Genotype (G) " and "Genotype x Environment (GxE) Interaction" make these two factors relevant for the multi-environmental evaluation of these mung bean accessions as reported by [14]. So, the significance of genotype x environment interaction deserves high priority in any crop improvement program [12]. Also, [12] reported that GGE-biplot analysis facilitates the evaluation of target regions for their discriminatory ability and representativeness for different genotypes in a trial. In fact, Pobé, Saria and Kamboinsé are located to different agro-climatic zones [15] and so, experience rainfall that varied in time and space, which would have influenced the performance of mung bean accessions. Pobé (in the Sahelian) zone with 594.3 mm and Kamboinsé with 833. 9 received less water than Saria (872.5mm). Also. despite the fact that Kamboinsé and Saria belong to the same agro-climatique zone (Sudano-Sahelian zone), different rainfall amounts and temporal distributions were observed in these two locations. Also, the heavy rains received by Saria in a short time and at a critical period of the plant development, may have affected mung bean production. In contrast to Kamboinsé where they were more spread out and to Pobé with much lower rainfall. According to [16], heavy rains in the middle of pod ripening can cause premature germination and lead to the formation of low-quality seeds, in addition to the root damage that [17] reported in submerged areas. The relatively good performance of majority of these accessions in Pobé and Kamboinsé despite the fact that these two sites belong to very distinct climatic zones, with Pobé being in the most arid zone, is due to the fact that mung bean is a drought tolerant legume and its cultivation therefore does not require large amounts of water [18]. The adaptability of these mung bean accessions to different growing areas, based on the spatio-temporal distribution of rainfall, was revealed by seeds harvested per plant. Indeed, at this stage of the experiments, some genotypes seem more or less adapted than others to one or more environments. However, very abundant rainfall over a short period of time may have affected the productivity of mung bean in Saria. The same situation was reported by [11]. Thus, based on the average performance in terms of seeds harvested per plant, accessions V 2709; VC 1481A/VC 1560A; NM 94 and 9154 were the best at Pobé, while PLM 944; KPS2; Kyungkijaerae 16 and VC 1168D/VC1560A were the best at Kamboinsé. Indeed, according to [19], [20], in multi-location yield trials changes in the relative ranking of genotypes from one environment to another may result from genotype by environment interactions that may occur. In this study, the contribution of genotype x environment interactions (GEIs) to the expression of variability was 29.61%. Based on this contribution, GGE biplot analysis allowed us to identify the most favorable environments for mung bean experimentation in terms of the seeds harvested per plant. These sites are: Kamboinsé and Pobé. These two sites, due to the average performance of the accessions, which resulted in relatively long environmental vectors in the GGE biplot analysis, are the most discriminating sites and the most favorable for identifying specifically adapted mung bean genotypes. Also, a strong correlation may exist between the site of Pobé and that of Saria even if this last one did not constitute a favorable site at this stage of the experiments. This correlation between these two sites could be judiciously exploited if it is confirmed following additional experiments. The presence of close associations between different environments suggests that the same information about genotypes in experimentation could be obtained from fewer test environments and thus, the possibility of reducing the cost of testing [21]. But Promising genotypes need to be evaluated in multi-environmental test over several years for identification of the stable and widely adapted genotypes [12]. This study also identified the most stable genotypes, regardless of whether they were high or low yielding in terms of seeds harvested per plant. [11] reported that the ranking performed by the GGE biplot analysis is not only based on yield but also on stability. Also. according to [22], low-yielding genotypes in poor environments tend to be in the lower left quadrant as is the case in our study of genotypes: Chunbukjaerae2 and 13584 which averaged 5. 05 g/pl and 9.69 g/pl. respectively. This is also the case for the genotype EWVN (Commercial variety) with 7.83g/pl.

4 Conclusion

The variability of responses of the different mung bean accessions regarding the experimental sites, analyzed using the GGE double projection, allows at this stage to identify the environments that are favorable for future experiments, and the best performing genotypes by location. So, at this stage of the experiments, the sites of Kamboinsé and Pobé seem to be the most favorable for mung bean cultivation. In addition, and an important outcome for this study is that the best performing accessions in Pobé area which is the driest part of the country appear to be accessions adapted to drought. However, it would be necessary to conduct additional trial in terms of year and environment in order to better study the adaptability of mung bean in Burkina Faso and to identify genotypes with broad adaptation. i.e., covering the different agroclimatic zones of the country.

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