Journal of Agriculture, Food, Environment and Animal Sciences
http://www.jafeas.com, ISSN: 2757-5659
https://doi.org/10.5281/ 10.5281/zenodo.20396247

J. Agric. Food, Environ. Anim. Sci.
7(1): 1-16, 2026

Influence of Different Agro-Ecologies on the Performance and Adaptation of Mung Bean (*Vigna radiata* L.) in Nigeria

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Research Article

Article History:
Received: 02 May 2025
Accepted: 24 February 2026
Published online: 26 May 2026

Keywords:
Climate
Crop Improvement
Underutilized Legumes
Productivity
Regression

ABSTRACT

Twenty-one mung bean genotypes were evaluated in three agro-ecologies in two years to identify suitable environment for optimum production of the crop in Nigeria. The experiment was laid out in a randomized complete block design with three replications. Data were collected on agronomic and yield parameters. Analysis of variance and regression analyses were conducted on the weather and field data using SAS. Mean square of year by location was significant for all the parameters except pod and seed yield. Mean square of genotype was also significant for all the parameters except pod yield. Yield was generally highest at Ile-Ife followed by Kishi. However, there were variations in the yield in different years. The regression analysis revealed that a unit change in temperature will bring about a reduction of 3.32 and 0.31 (for minimum and maximum temperature, respectively) units in seed yield. A unit change in rainfall brought about 0.01 unit change in seed yield. Rainforest zone is the most suitable environment for optimum mung bean production.

To Cite : Oloyede-Kamiyo QO, Adewumi AD, Oladipo MS, Ukachukwu PC., 2026. Influence of Different Agro-Ecologies on the Performance and Adaptation of Mung Bean (Vigna radiata L.) in Nigeria.Agriculture, Food, Environment and Animal Sciences, 7(1): 1-16. https://doi.org/10.5281/ 10.5281/zenodo.20396247

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INTRODUCTION

Mung bean (*Vigna radiata* L.) is a vital legume crop, native of Indian subcontinent and widely cultivated in Asia particularly in India, China, Korea and Thailand. It is also grown in dry tropical and subtropical regions including the Caribbean and parts of Africa (Ullah et al., 2011). It is known for its nutritional value and adaptability to various agro-ecological zones (Sequeros et al., 2021). Mung bean plays a crucial role in addressing food security concerns, especially in regions with high population growth and limited arable land (Habtamu et al., 2024). Its high protein content and short growing period, and ability to improve soil fertility through nitrogen fixation makes it an ideal crop for improving dietary diversity and nutritional security (Sequeros et al., 2021, Habtamu et al., 2024).

Mung bean is highly digestible and free from flatulence effect commonly associated with many grain legumes. It is a rapidly growing, multi-branched plant, and 0.5-1.0 m tall. The pod is long and slender with 10-20 seeds and grey to black in colour when mature. Seed is globular in shape with 100 seeds weighing between 3-4 g. It has 19-21% protein, 3.0- 3.5 % fat, 56-57 % Carbohydrate (CHO), 4.0 % fibre, and 4.0 – 5.0 % ash (Oloyede-Kamiyo et al., 2024). Mung bean grows well in warm humid climate with temperature range of 25 - 35 ^{o}C and 400 - 500 mm rainfall well distributed during the growing period of 80-120 days. It grows in wide range of soil type including clayey soils, but grows best on well-drained soil with pH range of 6.2- 7.2.

The crop is just gaining traction among farmers in Nigeria due to its nutritional benefits. No specific annual production figure is available, and breeding efforts on the crop is still in the early stage. Yield ranges between 500 and 2500 kg ha^{-1} (Parihar et al. (2022).

Climate change poses significant challenges to crop production. Studies have shown that the crop is sensitive to temperature fluctuations, with optimal growth occurring between 25 and 30 °C (Sarkar et al., 2017). Adaptation strategies, such as selecting heat-tolerant varieties, adjustment of sowing dates, and adoption of suitable agronomic practices are essential to mitigate the impacts of climate change and optimize crop performance (Sarkar et al., 2017; Sequeros et al., 2021).

Parihar et al. (2022) assessed the performance of mung bean genotypes in different Indian climates and emphasized the need for location-specific breeding strategies to maximize yield and adaptability. The knowledge of suitable agro-ecology will enhance improvement for specific traits such as drought tolerance, heat resistance, and disease resistance. It will also provide a broader perspective on the best environmental conditions for crop production, efficient use of resources (use of available water and nutrient) and climate resilience. This study, therefore, aims at identifying the best agro-ecology for optimum mung bean production as a strategy to improve it for climate resilience.

MATERIALS AND METHODS

The Mung Bean Genotypes

Twenty one mung bean accessions obtained from the International Institute of Tropical Agriculture (IITA), Nigeria were used for this study. The accessions consisted of 19 green gram and 2 black gram genotypes. The seeds are globular in shape with white eye colour.

The Study Locations

The study was conducted in three locations in 2022 and 2023. The three locations- Ile-Ife, Kishi and Ibadan, cut across three different agro-ecologies in Nigeria. The map showing the study locations is presented in Figure 1. Ile-Ife, Osun State is a rainforest zone. It is located at Longitude 4.61 E and Latitude 7.46 N and altitude 280 m above sea level (asl). Ile-Ife soil is classified as Ultisols, typically acidic, with low nutrient reserves, low available phosphorus and high exchangeable bases. Kishi, Oyo State is Northern Guinea savanna on Long. 3.96" Lat. 9.0" and altitude 150 m asl (Figure 1). Kishi soil is classified as Arenic Kandiudults and Arenic Kanhapludults according to USDA soil taxonomy. The soils are sandy with low cation exchange capacity (CEC) and potassium deficiency. Ibadan, Oyo State is Derived savanna on Long. 3.86", lat. 7.36" and altitude 213 m asl. The soil is classified as Arenic Kandiudults and Arenic Kanhapludults according to USDA soil taxonomy, similar to those of Kishi with sandy texture, and low CEC.

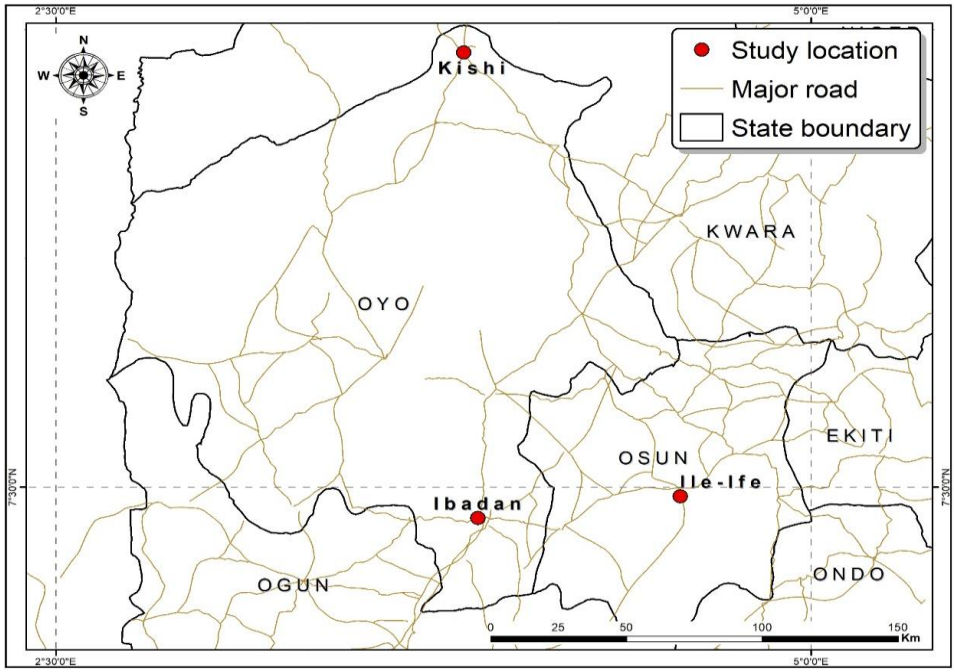


Figure 1. Map showing the study locations

Weather Condition of the Locations

The weather data for the locations were sourced from the Nigerian Meteorological Agency (NiMet), Nigeria and presented in Table 1. Ile-Ife had annual total rainfall of 1346 and 1221 mm in 2022 and 2023, respectively. The total rainfall during the evaluation period (May -July) in 2022 and 2023 in Ile-Ife was 754.4 and 556.3 mm, respectively. Temperature ranged from 22 to 32 ^{o}C in 2022 and 23 to 33 ^{o}C in 2023. Average relative humidity was 82 % in 2022 and 78 % in 2023.

Kishi had annual total rainfall of 981 and 966 mm in 2022 and 2023, respectively. The total rainfall during the growing period (May -July) in 2022 and 2023 in Kishi was 634 and 553 mm, respectively. Temperature range from 22 to 33 ^{o}C in 2022 and 22 to 32 ^{o}C in 2023. Average relative humidity was 83 % in 2022 and 84 % in 2023.

Ibadan had annual total rainfall of 1369 and 1232 mm in 2022 and 2023, respectively. The total rainfall during the growing period of the mung bean (May -July) in 2022 in Ibadan was 579.7 mm, while in 2023, the total rainfall during the growing period was 615.9 mm. Temperature range from 23 to 33 ^{o}C in 2022 and 23 to 32 ^{o}C in 2023. Average relative humidity was 82% in 2022 and 2023.

Table 1. Weather data at the study locations in 2022 and 2023

Location	Year	Rainfall (mm)		Relative humidity (%)	Temperature (°C)		
		Annual total	During growth period (May-July)		Mean	Max.	Min
Ile-Ife	2022	1346	754.4	82	27	22	32
	2023	1221	556.3	78	28	23	33
Ibadan	2022	1369	579.7	82	28	23	33
	2023	1232	615.9	82	27.5	23	32
Kishi	2022	981	634	83	27.5	22	33
	2023	966	553	84	27	22	32

Source: Nigerian Meteorological Agency (NiMet), Nigeria

Field Evaluation

Planting was carried out in May and June in all the locations in both years. Randomized complete block design in three replications were used to lay out the experiment. The plot size was 2.4 m x 2.4 m, with a spacing of 0.6 m between plants within plots and 1.0 m between plots. Three seeds were sown per hole and later thinned to two plants per hill to give a total of 50 plant stands per plot. Pre-emergence herbicide (Metolachlor 960 gE.C. at 1.44 kg ai ha^{-1}) was applied at planting. Weeding was done as and when due using hoe to keep the field weed free. Magic Force (Lambda-cyhalothrin 15 % + Dimethoate 300 g L^{-1}) insecticide was sprayed at the vegetative and reproductive stages against insect pests.

Parameters Assessed

Days to first flowering and podding were recorded by counting the number of days from planting to when flower and pod was first noticed per plot, respectively. Plant height (in centimeter) was taken at full podding by measuring the plant from the soil surface to the tip of main stem using measuring tape. Average of five plants was taken per plot for the measurement. Days to maturity was recorded as number of days from planting to when the plants in a plot reach 95 % senescence. Pods per plant was taken by dividing the total number of pods per plot by the number of plants per plot at harvest. Number of main branches was taken by counting the number of main branches on five plants per plot, and the average recorded. Pod and Seed weights (kg per plot) were taken by weighing all the pods before threshing and seeds after threshing the dry pods per plot, respectively.

Statistical Analyses

Mean, standard error and range were estimated. Means were estimated for each year and for the two years combined. Combined analysis of variance was also estimated for the three location and the two years. The means of weather data for locations and years were regressed on the mean seed yield to determine the effect of change in weather parameters on seed yield.

RESULTS and DISCUSSION

Mean squares from combined analysis of variance across locations and years is presented in Table 2. Mean square of location was significant for days to first podding and seed yield per plot, while mean square of year was significant for only seed yield per plot. Mean square of location by year was highly significant for all the parameters studied except pod and seed yield. Mean square of genotype was significant for all the traits studied except pod yield. Mean square of genotype by location was significant for only plant height and number of main branches, while mean square of genotype by location by year was significant for only number of days to first flowering. However, mean square of genotype by year was not significant for any of the traits.

The mean performance of the accessions across locations and years is presented in Table 3. Average plant height at maturity was 75.86 cm with accessions 10 being the tallest (102 cm). The mean number of days to first flowering and podding was 43 and 47 days, respectively. Accession 21 was prominent among the earliest with 39 and 44 days to first flowering and podding respectively, while accessions 5 was the latest. The accessions matured at average of 77 days after planting. Number of main branches and pods per peduncle were 4. Mean pod and seed yield per plot was 1.73 kg per plot and 1.17 kg per plot, respectively.

Table 2. Mean squares from combined analysis of variance for the traits assessed in the mung bean accessions at the three locations in 2022 and 2023

Source of Variation	df	Days to first flowering	Days to first podding	Plant height (cm)	Days to maturity	Number of pods/peduncle	Number of main branches	Pod yield/plot (kg)	Seed yield/plot (kg)
Location (L)	2	670.60	1182.61**	3864.67	2758.88	0.84	15.80	51.29	51.88**
Year (Y)	1	650.15	138.57	36043.10	2631.13	0.11	1.51	12.51	4.94**
L x Y	2	235.92**	361.14**	23166.10**	1341.96**	1.41**	2.06**	104.69	0.001
Rep (Lx Y)	12	54.12**	66.47	277.60	7.75	0.17**	0.28**	15.62**	3.97**
Genotype (G)	20	109.85**	128.07**	707.58**	95.37**	0.12*	0.08**	1.05	0.88**
G x L	40	20.60	27.51	708.64**	16.48	0.03	0.06*	0.93	0.56
G x Y	20	23.09	29.91	210.77	31.68	0.05	0.02	1.28	0.28
G x L x Y	40	21.70**	32.25	145.45	24.62	0.03	0.03	1.42	0.18
Pooled error	240	11.42	25.43	153.67	23.53	0.03	0.05	1.42	0.61

*, ** : significant at 5% and 1% level of probability, respectively.

Table 3. Mean performance of the mung bean accessions for the traits assessed across the locations between 2022 and 2023

Accession	Plant height (cm)	Days to first flowering	Days to maturity	Days to first podding	Number of pods/ peduncle	Number of main branches	Pod yield per plot (kg)	Seed yield per plot (kg)
1	63.11	41.78	73.80	45.11	4.84	4.05	2.23	1.18
2	73.25	43.78	77.27	47.17	4.28	4.37	1.45	0.82
3	66.34	41.89	94.53	45.30	4.74	4.45	1.89	1.47
4	69.22	43.67	74.07	47.70	4.81	4.30	2.43	1.80
5	90.07	49.77	78.29	52.88	4.23	4.17	1.68	1.24
6	80.51	40.83	75.93	44.17	4.25	4.33	1.77	1.22
7	75.00	41.44	75.29	44.83	4.27	4.11	2.05	1.50
8	88.60	46.18	79.00	49.12	4.60	4.51	1.77	1.31
9	68.38	42.89	76.87	44.59	4.36	4.42	1.20	1.13
10	102.14	46.71	84.43	50.88	3.53	5.09	1.14	0.38
11	80.31	43.39	78.60	46.83	4.28	5.02	1.77	1.25
12	72.03	42.28	77.73	47.83	4.40	4.40	1.87	1.25
13	68.38	42.17	75.57	44.28	4.40	4.38	1.67	1.15
14	75.09	41.94	78.07	44.06	4.48	4.28	1.70	1.43
15	74.70	44.89	76.85	47.44	4.22	4.12	2.17	1.50
16	69.86	40.50	75.00	43.94	4.45	4.44	2.01	1.43
17	70.09	41.24	73.86	44.28	4.37	4.74	1.22	0.78
18	66.26	43.44	76.00	46.50	4.51	4.45	1.55	1.02
19	95.82	46.59	82.14	51.59	3.50	4.89	1.72	0.78
20	72.32	43.56	76.60	46.78	4.99	4.76	1.91	1.30
21	88.64	39.11	79.14	43.89	3.61	3.96	1.46	0.75
Mean	75.86	43.20	77.08	46.57	4.35	4.44	1.73	1.17
SE	1.86	0.91	1.31	1.28	0.18	0.18	0.10	0.15
CV (%)	16.34	7.82	6.29	10.83	17.85	23.32	69.00	64.17

SE: Standard error; kg: kilogram; cm: centimeter; CV: coefficient of variation

Accessions with highest pod yield were accessions 4, 1, 15, 7 and 16 in that order (2.43, 2.23, 2.17, 2.05 and 2.01 kg per plot, respectively), while accessions with highest seed yield were accessions 4, 15, 7, 3, 16, and 14 in that order (1.8, 1.5, 1.5, 1.47, 1.43, 1.43 kg per plot, respectively).

Pod yield of the accessions was highest at Ile-Ife (Rainforest ecology) across the two years (Figure 2). The performance was not different between Kishi (Northern Guinea savanna) and Ibadan (Derived savanna) except for very few accessions. Seed yield followed the same trend (Figure 3). In 2022, pod yield was highest at Ile-Ife followed by Kishi (Figure 4), while in 2023, the performance was highest at Kishi (Figure 5). However, performances of some of the accessions were not different at the three locations in 2023. Half of the accessions actually performed better at Kishi (the Northern Guinea savanna) than Ile-Ife (Rainforest ecology) (Figure 5). On the average, pod yield was highest at Ile-Ife followed by Kishi in 2022, but highest at Kishi followed by Ibadan in 2023 (Figure 6).

Temperature (minimum and maximum) and rainfall had significant effects on the seed yield performance of the mung bean accessions. Effect of relative humidity was, however, not significant (Table 4). The regression analysis revealed that a unit change in temperature would cause a reduction of 3.32 and 0.31 (for minimum and maximum temperature, respectively) units in seed yield. A unit change in rainfall would cause 0.01 change in seed yield, and a unit change in relative humidity would bring about 0.5 change in seed yield

Table 4. Regression of weather data on seed yield of the mung bean accessions evaluated at the three locations in 2022 and 2023

Source	Coefficient	SE	t	P |t|	Confidence Interval
Relative Humidity	0.51	0.40	1.41	0.16	-0.23 - 1.35
Temp Min	-3.32	0.39	-8.40	0.000	-4.09 - 2.53
Temp Max	-0.31	0.11	-2.79	0.006	-0.54 - 0.09
Rainfall	0.01	0.002	4.52	0.000	0.006 - 0.15
Constant	26.51	30.14	0.88	0.38	-32.89 - 85.9

SE: Standard Error; P: probability

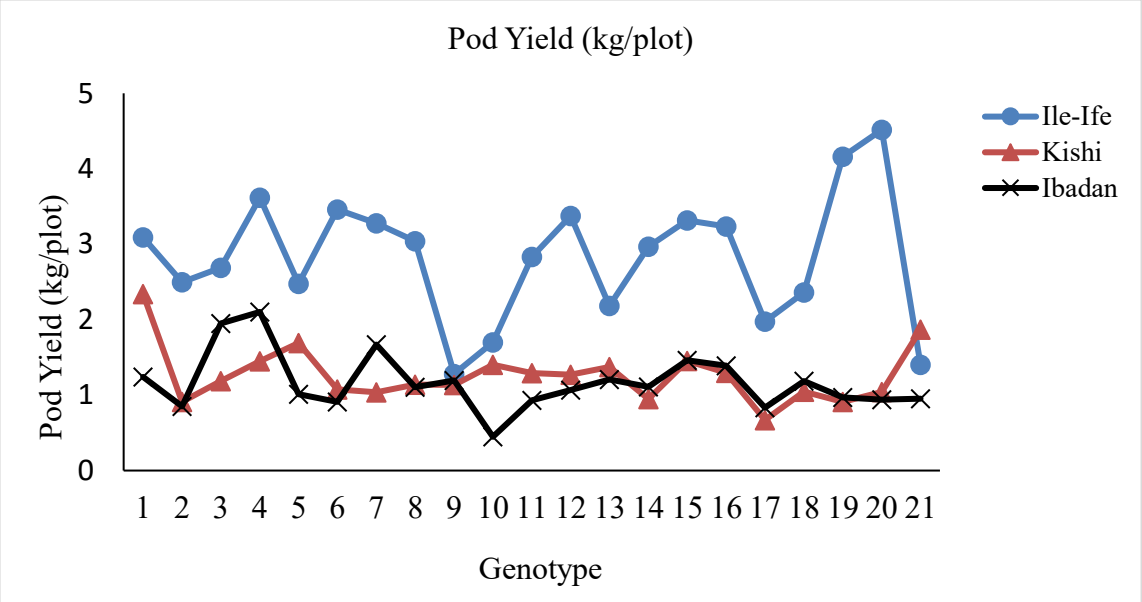


Figure 2. Mean pod yield per plot (kg) of the mung bean accessions across environments

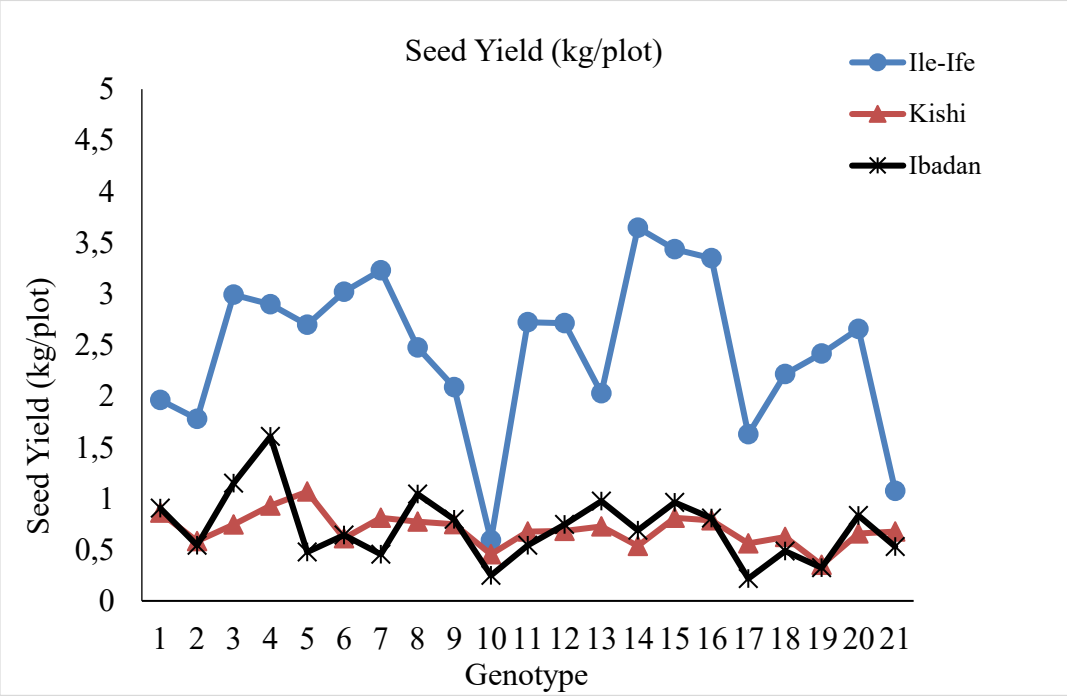


Figure 3. Mean seed yield per plot (kg) of the mung bean accessions across environments

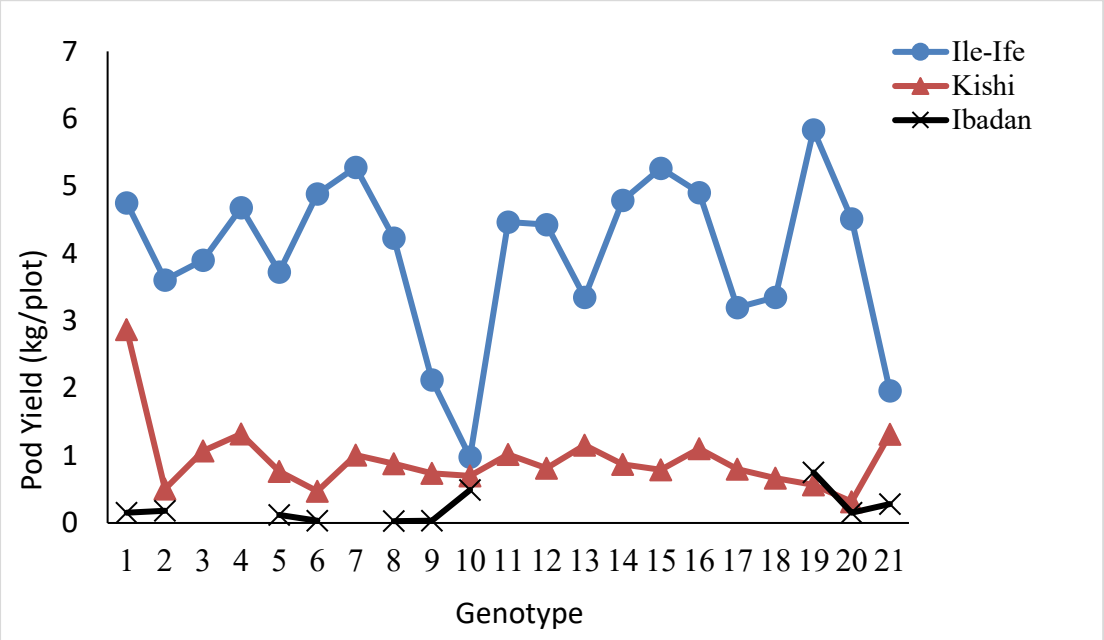


Figure 4. Pod yield per plot (kg) of the mung bean accessions at the three locations in 2022 cropping season

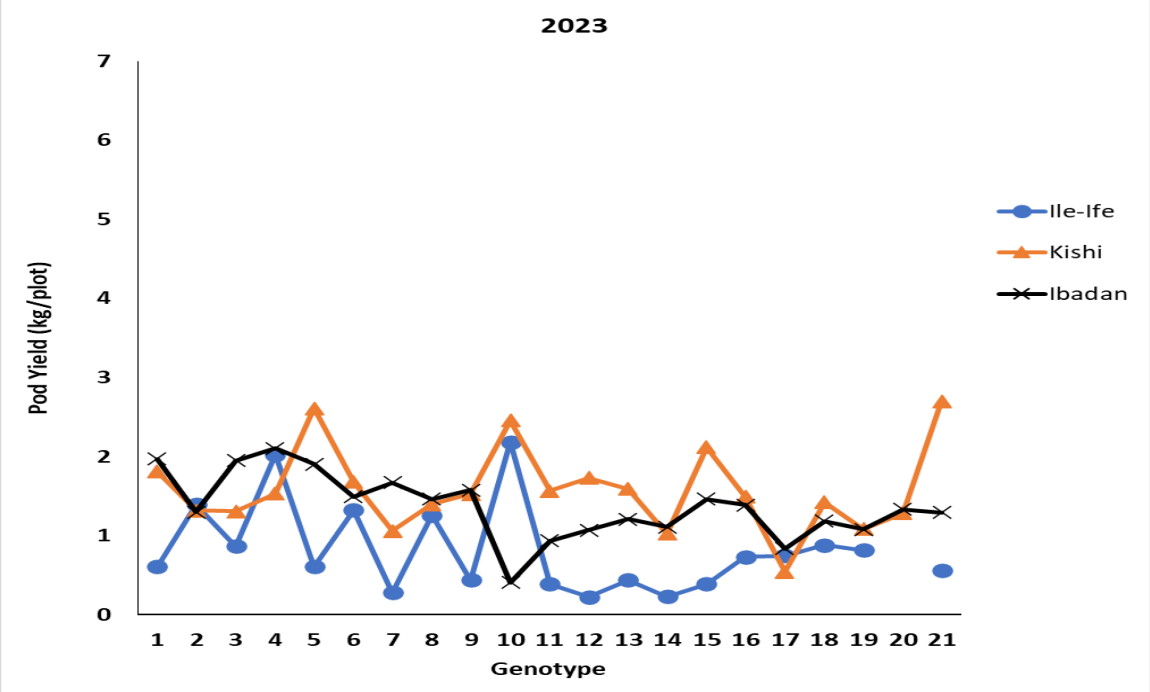


Figure 5. Pod yield per plot (kg) of the mung bean accessions at the three locations in 2023 cropping season

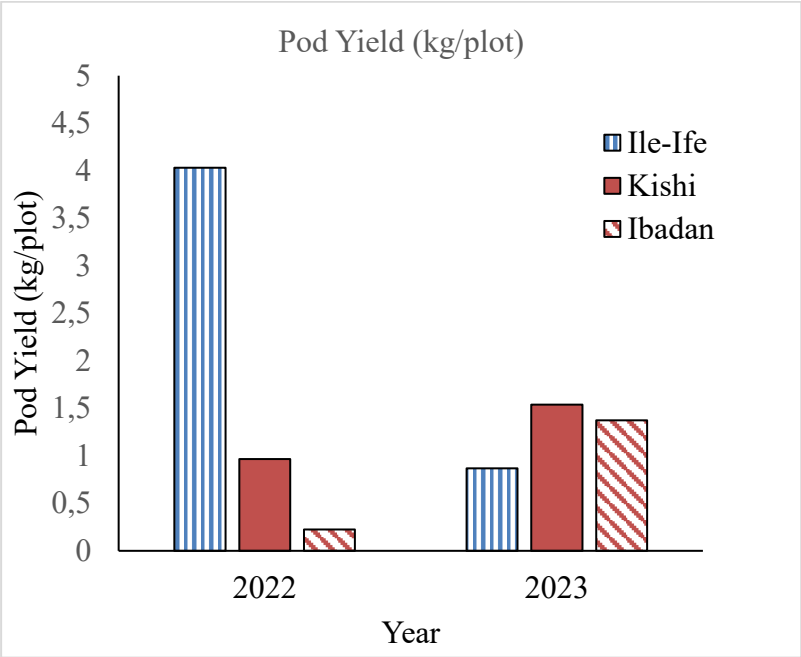


Figure 6. Mean pod yield (kg) in the three locations in 2022 and 2023

DISCUSSION

There are significant variability among the mung bean accessions in parameters such as plant height, flowering time, and seed yield across the three agro-ecological zones. Plant height ranged significantly, with accession 10 being the tallest, indicating its suitability for biomass production for livestock feed. However, shorter accessions such as accession 1 could be advantageous in areas with high wind velocities, where plants are prone to lodging (Bourgault et al., 2013). Mung bean accessions tend to exhibit better vegetative growth in environments with moderate temperatures (25-30 °C) and adequate soil moisture (Nair et al., 2019).

Early flowering and podding of accession 21 makes it a promising candidate for short-season environments, especially where water is limiting or the growing season is short (Mogali and Hedge, 2020) and can also be valuable for double planting within the cropping season. Contrarily, late-maturing accessions such as accession 5 could be targeted for extended growing seasons, allowing maximum biomass and seed production (Barpete et al., 2023). Late-maturing accessions may have a higher yield potential as emphasized by Adhikari et al. (2018). The performance of mung bean accessions revealed considerable genotype-environment interactions, emphasizing the need for targeted breeding programs to enhance yield stability and environmental

adaptation. The variation in flowering time suggests the influence of photoperiod sensitivity, genetic background and prevailing climatic conditions (Chauhan and Williams, 2018). At locations with higher temperatures and lower humidity, flowering was slightly earlier, aligning with previous studies that mung bean flowers earlier under heat stress conditions (Priya et al., 2023). Similarly, in regions with high rainfall and cooler temperatures (Ile-Ife and Ibadan), late maturity was observed, while at Kishi, which has lower rainfall and higher temperatures, maturity was slightly earlier as also observed by Adhikari et al. (2018). The variability in number of main branches may possibly be due to differences in soil nutrient and spacing (Olorunfemi et al., 2018). The high variability in pod yield per plot aligns with the findings of Oloyede-Kamiyo et al. (2024).

The highly significant mean square of location for days to first podding and seed yield suggests that environmental factors such as soil properties, rainfall distribution, and temperature variations across the three locations played a crucial role in the expression of these traits. Ile-Ife which has better soil moisture retention and organic matter, with high rainfall supported higher yields compared to other locations. Year effect was significant for seed yield, implying that seasonal variations influences seed yield performance. The significant location by year interaction effect for traits, such as days to first flowering and podding, pods per peduncle, plant height and number of main branches indicates differential genotypic responses to weather conditions across years, a pattern observed in previous studies on mung bean (Samyuktha et al., 2020). Higher temperatures and low soil moisture in Kishi may lead to shorter plants, while higher rainfall in Ile-Ife and Ibadan may result in taller plants (Nair et al., 2019).

Mean square of genotypes was highly significant for almost all the traits, suggesting the existence of genetic variability among the mung bean accessions. High genotypic variability coupled with non-significant genotype by year (G×Y) interactions is desirable for breeding, as it allows for the selection of superior accessions with stable performance across different environments (Teklu et al., 2021).

The variation in pod and seed yield across locations and years suggests differential adaptation of accessions to specific environments. Studies have shown that mung bean is sensitive to temperature fluctuations, with optimal growth occurring between 25 °C and 30 °C (Sarkar et al., 2017). In the present study, Ile-Ife (Rainforest ecology) supported higher yields in 2022 which is likely due to favorable rainfall (754 mm) and moderate temperature, while Kishi (Northern Guinea savanna) exhibited better performance in 2023, possibly due to variations in the rainfall pattern within the growing season in the location or temperature fluctuations. This shift in yield performance across years highlights the need for location-specific recommendations to optimize production, and the importance of multi-location trials to identify broadly adapted and stable genotypes (Hammer et al., 2014, Birachi et al., 2023).

The regression analysis revealed the detrimental effects of temperature fluctuation on seed yield, where increase in minimum and maximum temperature led to between 0.31 - 3.32 units reduction in yield. High temperatures and water stress during critical reproductive stages may impair pollination and pod formation, and will also affect photosynthesis leading to low yield, corroborating the existing literatures on mung bean sensitivity to heat stress (Mahajan et al., 2023, Priya et al., 2020). Low night temperatures could affect the physiological processes, such as respiration and nutrient assimilation, leading to yield reduction, a pattern also observed by Meena et al. (2021). More specifically, increase in average global temperature has the ability to significantly affect germination rates as well as plant productivity (Zhao et al., 2017).

Optimizing agronomic practices, such as timely planting and efficient water management, could further enhance productivity as opined by Praharaj et al. (2016). Plants under well-watered and ambient temperature environments will develop larger canopy, thereby increasing photosynthetic capacity to accumulate enough resources to increase the number of pods per plant (Mahajan et al., 2023). This result suggests that mung bean will do well in an environment with high rainfall, evenly distribution within the growing period with moderate temperature ranging between 23-32 °C as experienced at Ile-Ife in 2022. However, excessive rainfall beyond optimal levels could lead to waterlogging, which was not analyzed in this study but has been reported to negatively affect legume crops (Pucciariello et al., 2019).

CONCLUSION

This study confirmed significant environmental effects on mung bean growth and yield, with temperature, rainfall, and soil type influencing performance. The shift in pod and seed yield across years and locations highlights the importance of multi-location and multi-year trials to identify genotypes with broad adaptability and stability. The Rainforest zone is a suitable agro-ecology for optimum mung bean production in Nigeria. However, breeding efforts should focus on developing heat-tolerant genotypes to mitigate the adverse effects of rising temperature occasioned by climate change.

ACKNOWLEDGEMENTS

The authors appreciate the members of staff of Ibadan, Ile-Ife and Kishi out-station of IAR&T for their technical assistance.

Conflict of Interest

The authors have declared that there are no competing interests

Authors Contribution

Authors contributed equally toward the study

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