Journal of Underutilized Legumes
Vol. 6 (2): 8 - 17

Society for Underutilized Legumes
https://sulegumes.org/
e-ISSN: 2705-3776

Evaluation of Some Plant Parasitic Nematode Associated with Lima Bean (*Phaseolus Lunatus*)

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Received October 25, 2024
Accepted for publication November 30, 2024
Published January 16 2025

Abstract

Plant-parasitic nematodes significantly impact agricultural systems, particularly legumes such as lima beans (*Phaseolus lunatus*), which are highly susceptible to infestation. A field study was conducted at the Institute of Agricultural Research and Training, Ibadan, Nigeria, (latitude at 07^0 22’’N, 3^0 50’’E) South West Nigeria, in 2022 and 2023 respectively to evaluated the effects of plant-parasitic nematodes on fifteen lima bean landraces collected from four Nigerian states (Osun, Ondo, Ekiti, and Oyo). The landraces were grown in a naturally nematode infested field. Nematode populations were assessed at pre-planting and harvest maturity, with soil samples collected to a depth of 0–30 cm. Insect control was achieved using lambda cyhalothrin, applied during flowering and podding. Growth, yield, and nematode parameters, including gall numbers data were collected and analysed using ANOVA and Pearson’s correlation in STAR © 2013 software. The results revealed significant variability in nematode susceptibility among landraces. Aramoko Ekiti exhibited the highest *Meloidogyne* spp. populations, while Tede Oyo showed the lowest, suggesting better resistance. Erin Ijesha recorded the highest *Pratylenchus* spp. populations, while Aisegba had the lowest. *Helicotylenchus* spp. populations were consistently lowest in Aisegba across both years. Growth and yield parameters also varied significantly, with Ikogusi Ekiti achieving the highest shoot weights and Budo Bank Ago Amudu demonstrating superior root health. Early flowering was observed in Tede Oyo and Erin Ijesha, while Ikogusi Ekiti and Erin Ijesha had the longest pods and highest seed counts in 2023.

Keywords: Lima bean, Plant parasitic nematodes, *Meloidogyne*, *Pratylenchus*, *Helicotylenchus*, Nematode management

Introduction

Lima bean (*Phaseolus lunatus* L.), a leguminous crop of significant nutritional value, holds untapped potential in addressing food and nutrition security challenges in sub-Saharan Africa. In Nigeria, however, lima bean cultivation remains underutilized despite its high protein (23%) and fiber (6%) content, as well as its suitability for cultivation in low-fertility soils and drought-prone regions. While this crop can play a vital role in enhancing dietary diversity and resilience to climate change, its production is constrained by several factors, including susceptibility to plant-parasitic nematode. In Nigeria, lima beans are recognized as an underutilized crop, offering substantial potential for enhancing food and nutrition security. The term underutilized refers to their limited commercial cultivation, low awareness among farmers, and lack of presence in national agricultural systems and also reflects the potential for expanding their role in the Nigerian diet, where protein demand continues to grow amid increasing population pressure [1]. Despite these nutritional benefits, lima beans remain less prevalent in Nigeria compared to other legumes such as cowpeas and soybeans [2]. Furthermore, their

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resilience to poor soils and climate variability presents a promising opportunity for food security, especially in drought-prone and low-fertility regions according to Sanni et al. [3]. However, challenges such as limited awareness, lack of improved varieties, and vulnerability to pests like nematodes restrict their widespread adoption.

Nematode infestations, particularly plant-parasitic nematodes, pose a significant threat to lima bean production. Despite the high relevance of nematodes to food security, there is limited research on the species affecting lima beans in Nigeria according to Olanrewaju et al. [4]. Plant-parasitic nematodes are among the most destructive pests in agriculture, causing yield losses estimated at 12–15% in legume crops globally as reported by Jones et al. [5]. These pests, particularly *Meloidogyne* spp. (root-knot nematodes), are known to stunt growth, reduce productivity, and in severe cases, lead to plant mortality [6]. The limited awareness of nematode infestation and the absence of targeted pest management strategies for lima beans further exacerbate the problem in Nigeria according to Adegbite et al. [7]. Moreover, the specific nematode species affecting lima beans, their prevalence, and their impact on crop yield in the diverse agro-ecological zones of South-West Nigeria remain poorly documented as reported by Coyne et al. [8]. This research aims to address this gap by identifying nematode species impacting lima beans, assessing their prevalence across different agro-ecological zones of Nigeria, and evaluating their effects on Lima bean growth and yield. Therefore, this study was carried out to identify plant-parasitic nematodes affecting lima beans across South-West Nigeria and assess their impact on the growth and yield of the crop.

Materials and Methods

Experimental site and source of Experimental Materials

A field experiment was conducted during the early seasons of 2022 and 2023 at the Institute of Agricultural Research and Training farm in Ibadan (latitude 07°22'N, longitude 03°50'E) within the derived savannah/transition agro-ecology of Southwest Nigeria. The site sits at an altitude of 122 meters above sea level, with an average annual rainfall of 1220 mm and a mean temperature of 26°C. For the study, fifteen lima bean landraces were collected during a survey from four states in South-West Nigeria namely Ondo State (Ita ogbolu, Iju, Oba -Ile, Ogbese), Ekiti State (Aisegba, Ikogosi, Aramoko, Agbado), Osun State (Erin Ijesa, Esa-oke, Iwaraja, Otan-Ile) Oyo State (Igboho, Iseyin, Ago-Amodu, Tede) the method adopted were participatory rural appraisal and field survey**.** This approach involves engaging local communities to gather both qualitative and quantitative data through direct field surveys, farmer interviews and questionnaires. It combines traditional knowledge with scientific observations to assess cultivation practices, challenges, and trends.

Land preparation

Land preparation was carried out by manual slashing of the experimental site followed by mechanical ploughing and harrowing. The nematode population present in the soil was taken at pre-planting, mid-season and at harvest maturity. Five cores of soil samples were randomly collected from each plot with soil auger to a depth of 0-30 cm and bulked together to determine the initial and final nematode population in the soil. Lima been seeds were sown directly on the field.

Nematode Identification and Soil Analyses

Soil samples were collected for extracting nematodes in random sampling pattern from each plots early in the morning. Six soil core samples were randomly collected per plot at a depth of 0–30 cm and 2–4 cm away using a soil auger, then combined to form a composite sample. The samples were sealed in labeled polyethylene bags and taken to the laboratory for nematode extraction and identification. Each composite sample was thoroughly mixed to ensure uniformity, and a 250 g subsample was taken to determine the nematode population in the soil using [9]. The nematode extractor tissue paper was placed between two 15 cm-diameter plastic sieves, which were set in a 25 cm-diameter bowl. Each 250 g soil portion was evenly spread in the sieves, labeled, and arranged in the laboratory. Debris and pebbles were removed, and soil clumps were broken up to facilitate nematode movement into the water. Two hundred milliliters (200 ml) of water were carefully added to the bowl, and the setup was left undisturbed for 24 hours, after which the nematode suspension was poured into a 500 ml Nalgene bottle. Additional water was added to reach the marked fill line, and the bottle was left for 5 hours to allow the nematodes to settle. Excess water was removed using 3 mm rubber tubing. The concentrated 15 ml nematode suspension was transferred into a McCartney bottle and refrigerated for identification and population counting. The nematode population was estimated using a Doncaster counting dish (1962) under a stereomicroscope at 250x magnification, with 1 ml of the suspension pipetted into the dish for examination.

Table 1. Source of fifteen Lima bean Landraces multiplied at IAR&T, Ibadan during the 2022/2023 cropping season

S/N	*Lima bean landraces*	*Seed coat colour*	*Source of collection*	*LGA*
1	*Tede Oyo 1*	*Brown*	*Oyo State*	*Atisbo LGA*
2	*Erin Ijesha 1*	*Brown*	*Osun State*	*Oriade LGA*
3	*Budo Bank Ago Amudu*	*Brown*	*Oyo State*	*Saki East LGA*
4	*Atisbo Oyo*	*White*	*Oyo State*	*Atisbo LGA*
5	*Arugbadagbe*	*Brown*	*Osun State*	*Saki East LGA*
6	*Tede Oyo 3*	*Dark Brown*	*Oyo State*	*Atisbo LGA*
7	*Agbado Ekiti*	*White*	*Ekiti State*	*Gbonyin LGA*
8	*Pepelupe Red*	*Red*	*Oyo State*	*Atisbo LGA*
9	*Iseyin*	*Cream*	*Oyo State*	*Iseyin LGA*
10	*Aramoko Ekiti*	*Brown*	*Ekiti State*	*Ekiti West LGA*
11	*Ikogusi Ekiti*	*Brown*	*Ekiti State*	*Ekiti West LGA*
12	*Pepelupe Brick Red*	*Dark Red*	*Oyo State*	*Atisbo LGA*
13	*Tede Oyo 2*	*Mottled Brown*	*Oyo State*	*Atisbo LGA*
14	*Iju Ekiti*	*Cream*	*Ekiti State*	*Ifedayo LGA*
15	*Aisegba*	*White*	*Ekiti State*	*Gbonyin LGA*

Experimental Layout

The field experiment was set up in a Randomized Complete Block Design (RCBD) replicated three times. The experimental plots size were divided into plots measuring 4 m × 3 m (12 m²) with a 2 m alley between plots. Lima bean was sown at 1 m x 1 m spacing between rows and 75 cm × 25 cm within rows, with two seeds sown per hole. Lima bean plants were stalked one week after seedling emergence. Insect pests was controlled with three applications of Lambda cyhalothrin (Karate; 2ml/litre) once at flowering and twice at podding. Weeding was done manually as and when necessary, throughout the experimental period.

Data Collection

Data were collected on growth, yield parameter (pod length, 100 seed weight and total yield per plot) and nematological parameters (nematode population, number of galls, and gall index) were recorded from each plot.

Data analysis

All data were analyzed using analysis of variance and Pearson’s correlation test with the Statistical Tool for Agricultural Research (STAR) © 2013. Significant means were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

Plate 1: Lima bean planted on the field

Results

Mean of different nematodes population

Lima bean landrace Aramoko Ekiti had the highest population in both years, with 9830.00 in 2022 and 9540.00 in 2023 (Table 2). This suggests Aramoko Ekiti is particularly susceptible to *Meloidogyne* spp. landrace Tede oyo had the lowest population in both years (5923.33 in 2022 and 5483.33 in 2023), indicating it may have lower susceptibility or better resistance against *Meloidogyne* spp. Landrace Erin Ijesha consistently showed the highest population across both years, with 1872.00 in 2022 and 1532.60 in 2023, indicating significant susceptibility to *Pratylenchus* spp. Landrace Aisegba had the lowest population in 2022 (1044.30), with a slight increase in 2023 (1176.00) (Table 2).This suggests a relatively lower susceptibility to *Pratylenchus* spp. Landrace Agbado Ekiti had an exceptionally high population in 2022 (15833.00), dropping to 1113.33 in 2023. This suggests Agbado Ekiti might have high susceptibility but also shows a significant reduction, perhaps due to control measures or environmental factors. Landrace Aisegba showed the lowest populations across both years (1125.00 in 2022 and 829.00 in 2023), indicating it has a lower susceptibility or higher resistance to *Helicotylenchus* spp. Across all nematode species, there is an observable trend of population decrease from 2022 to 2023. (Table 2). This trend may result from improved management practices, crop rotation, resistance traits in the plants, or changes in environmental conditions.

Mean final egg population, number of galls and gall index in roots

The study revealed varying levels of nematode susceptibility among lima bean landraces (Table 3). In 2022, Iju Ekiti had the highest nematode egg population (8103.33), while in 2023, Aramako Ekiti led with 7443.33, followed by Pepelupe red and Iju Ekiti. Conversely, Budo Bank Ago Amudu consistently showed the lowest egg counts across both years. High gall counts were observed in Pepelupe brick red and Iju Ekiti in 2022, with Pepelupe brick red remaining high in 2023.Tede Oyo displayed better resistance, with the lowest gall counts in both years (22.33 in 2022 and 17.33 in 2023) Generally, egg populations and gall indices showed slight reductions from 2022 to 2023, potentially due to improved resistance or environmental factors. Most landraces displayed a high gall index (4.00), except Tede Oyo and Erin Ijesha, which showed minor improvements in resistance to galling in 2023. These findings suggest variability in nematode susceptibility among lima bean landraces.

Table 2: Mean of Nematode Population on 15 Lima bean Landraces Evaluated in Ibadan during 2022 and 2023.

	Meloidogyne spp.		*Pratylenchus* spp.		*Helicotylenchus* spp.	
Landraces	2022	2023	2022	2023	2022	2023
A1	5923.33^{e}	5483.33^{d}	1451.00^{bcd}	1111.33^{bcd}	1342.00^{bcd}	1002.00^{bc}
A2	7907.67^{abcde}	7644.67^{abcd}	1872.00^{a}	1532.6^{a}	1746.00a	1406.00^{a}
A3	6473.33^{bcde}	5790.00^{d}	1176.00^{de}	836.00^{cd}	1196.00^{cd}	856.00^{c}
A4	7453.33^{bcde}	6886.67^{bcd}	1161.33^{de}	861.33^{cd}	1064.00^{d}	844.00^{c}
A5	8186.67^{abcd}	6773.33^{bcd}	1488.00^{bcd}	1188.00^{abc}	1306.67^{bcd}	1086.67^{abc}
A6	7613.33^{bcde}	7263.33^{abcd}	1632.00^{ab}	1332.00^{ab}	1553.33^{ab}	1333.33^{ab}
A7	8610.00^{abcd}	8260.00^{abc}	1642.00^{ab}	1342.00^{ab}	15833.00^{ab}	1113.33^{abc}
A8	6700.00^{cde}	6350.00^{cd}	1580.00^{abc}	1140.00^{bcd}	1470.00^{abc}	1000.00^{bc}
A9	8920.00^{ab}	8630.00^{abc}	1248.00^{cde}	808.00^{d}	1179.33^{cd}	979.33^{c}
A10	9830.00^{a}	9540.0^{a}	1370.67^{bcde}	930.67^{cd}	1292.00^{bcd}	1092.00^{abc}
A11	9040.67^{ab}	8756.67^{ab}	1416.00^{bcde}	976.00^{cd}	1302.00^{bcd}	1102.00^{abc}
A12	7293.33^{bcde}	7003.33^{bcd}	1516.00^{abcd}	1076.00^{bcd}	1416.67^{abc}	1120.67^{abc}
A13	8823.33^{abc}	8303.33^{abc}	1414.67^{bcde}	1018.67^{bcd}	1396.67^{bcd}	1100.67^{abc}
A14	8906.67^{ab}	8386.67^{abc}	1256.00^{cde}	1136.00^{bcd}	1276.67^{bcd}	980.67^{c}
A15	8773.33^{abc}	8253.33^{abc}	1044.30^{e}	1176.00^{bc}	1125.00^{cd}	829.00^{c}
S. E±	52.66	61.47	15.43	13.80	13.06	13.06

Means along the same column with different alphabet are significantly different ($p \leq 0.05$) from each other
A1 Tede oyo 1; A2: Erin Ijesha 1; A3: Budo Bank Ago Amudu; A4: Atisbo Oyo; A5: Arugbadagbe;
A6: Tede Oyo 3; A7: Agbado Ekiti; A8: Pepelupe red; A9: Iseyin; A10: Aramoko Ekiti; A11: Ikogusi Ekiti; A12: Pepelupe brick red; A13: Tede oyo 2; A14: Iju Ekiti; A15: Aisegba; S.E: Standard Error

Table 3: Mean of Nematological Parameters for 15 Lima Bean Landraces Assessed in Ibadan in 2022 and 2023

	Egg Population		Number of Galls		Gall Index	
Landraces	2022	2023	2022	2023	2022	2023
A1	6836.67^{bcd}	6396.67^{abc}	22.33^{c}	17.33^{d}	3.00^{b}	3.0^{b}
A2	6710.00^{bcde}	6270.00^{abcd}	35.67^{ab}	30.67^{abc}	4.00^{a}	3.33^{ab}
A3	5553.33^{e}	5113.33^{cd}	36.00^{ab}	29.00^{c}	4.00^{a}	3.33^{ab}
A4	5663.33^{e}	5313.33^{cd}	40.67^{ab}	33.67^{abc}	4.00^{a}	4.00^{a}
A5	7223.33^{abc}	6873.33^{ab}	44.33^{ab}	37.33^{abc}	4.00^{a}	4.00^{a}
A6	6523.33^{cde}	6173.33^{abcd}	44.00^{ab}	39.00^{abc}	4.00^{a}	4.00^{a}
A7	7513.33^{abc}	6993.33^{ab}	34.00^{b}	29.00^{c}	4.00^{a}	4.00^{a}
A8	7786.67^{ab}	7266.67^{a}	43.33^{ab}	39.00^{abc}	4.00^{a}	4.00^{a}
A9	5735.33^{de}	5515.33^{cd}	44.33^{ab}	39.33^{bc}	4.00^{a}	4.00^{a}
A10	7663.33^{abc}	7443.33^{a}	38.33^{ab}	34.33^{abc}	4.00^{a}	4.00^{a}
A11	6543.33^{cde}	6323.33^{abcd}	44.00^{ab}	40.00^{ab}	4.00^{a}	4.00^{a}
A12	5898.67^{de}	5678.67^{bcd}	45.00^{a}	41.00^{a}	4.00^{a}	4.00^{a}
A13	7685.33^{abc}	6326.67^{abcd}	40.0^{ab}	36.00^{abc}	4.00^{a}	4.00^{a}
A14	8103.33^{a}	6200.00^{abcd}	45.67^{a}	39.67^{abc}	4.00^{a}	4.00^{a}
A15	6641.33^{cde}	5043.33^{d}	36.00^{ab}	30.00^{bc}	4.00^{a}	3.67^{ab}
	14.83					0.069
S. E±		19.29	12.91	12.94	2.63	

Means along the same column with different alphabet are significantly different ($p \leq 0.05$) from each other. A1 Tede oyo 1; A2: Erin Ijesha 1; A3: Budo Bank Ago Amudu; A4: Atisbo Oyo; A5: Arugbadagbe; A6: Tede Oyo 3; A7:

Agbado Ekiti; A8: Pepelupe red; A9: Iseyin; A10: Aramoko Ekiti; A11: Ikogusi Ekiti; A12: Pepelupe brick red; A13: Tede oyo 2; A14: Iju Ekiti; A15: Aisegba; S.E: Standard Error

Table 4: Mean Performance of 15 Lima Bean Landraces Assessed in Ibadan in 2022 and 2023

	Fresh Shoot Weight (g)		Fresh Root Weight (g)	
Landraces	2022	2023	2022	2023
A1	17.73^{bc}	15.03^{bc}	15.00^{ab}	12.30^{ab}
A2	26.27^{ab}	23.57^{ab}	11.20^{ab}	8.50^{ab}
A3	21.00^{bc}	18.30^{abc}	16.80^{a}	14.10^{a}
A4	15.43^{c}	12.73^{c}	9.00^{b}	6.30^{b}
A5	23.20^{abc}	20.50^{abc}	12.16^{ab}	9.47^{ab}
A6	18.00^{bc}	14.90^{bc}	14.77^{ab}	11.87^{ab}
A7	16.43^{bc}	13.33^{c}	9.63^{b}	6.73^{b}
A8	17.17^{bc}	14.07^{bc}	9.43^{b}	6.53^{b}
A9	20.80^{bc}	17.70^{bc}	13.00^{ab}	10.10^{ab}
A10	15.57^{c}	11.11^{c}	14.96^{ab}	9.12^{ab}
A11	30.78^{a}	28.17^{a}	12.98^{ab}	12.80^{ab}
A12	22.73^{abc}	19.43^{abc}	14.60^{ab}	11.50^{ab}
A13	15.30^{c}	12.00^{c}	12.77^{ab}	9.67^{ab}
A14	17.00^{bc}	13.70^{bc}	14.43^{ab}	11.33^{ab}
A15	21.53^{abc}	18.23^{abc}	14.10^{ab}	11.00^{ab}
S. E±	10.88	10.88	4.76	4.78

Means along the same column with different alphabet are significantly different (p≤0.05) from each other. A1 Tede oyo 1; A2: Erin Ijesha 1; A3: Budo Bank Ago Amudu; A4: Atisbo Oyo; A5: Arugbadagbe; A6: Tede Oyo 3; A7: Agbado Ekiti; A8: Pepelupe red; A9: Iseyin; A10: Aramoko Ekiti; A11: Ikogusi Ekiti; A12: Pepelupe brick red; A13: Tede oyo 2; A14: Iju Ekiti; A15: Aisegba; S.E: Standard Error

Mean plant weight, fresh shoot and root weight (g)

In 2022 and 2023, landrace Ikogusi Ekiti consistently exhibited the highest shoot weight, recording 30.78 and 28.17, respectively (Table 4). Other top performing landraces included Erin Ijesha 1, Arugbadagbe, Budo Bank Ago Amudu and Pepelupe brick red, which generally displayed higher shoot weights across both years. In contract, landraces Atisbo Oyo, Agbado Ekiti, Pepeplupe red, Aramoko Ekiti and Tede Oyo 2 had consistently lower shoot weights, with Aramoko Ekiti showing a notable decline to 11.11 in 2023.

Landrace Budo Bank Ago Amudu demonstrated exceptional root health, recording the highest root weights in both years (16.80 in 2022 and 14.10 in 2023). Conversely, landraces Atisbo Oyo, Agbado Ekiti and Pepelupe red had some of the lowest root weights, such as Atisbo Oyo's decline from 9.00 in 2022 to 6.30 in 2023. A general trend of slightly lower weights across most Landraces was observed in 2023 compared to 2022, suggesting potential environmental or growing condition changes (Table 4)

Table 5: Mean of Growth and Yield Parameters of 15 Lima Bean Landraces Assessed in Ibadan in 2022 and 2023.

	Pod length (cm)		No Seed/pod		Days to 50%F	
Landraces	2022	2023	2022	2023	2022	2023
A1	7.12^{b}	7.52^{b}	3.62^{b}	3.72^{b}	82.23^{h}	81.52^{k}
A2	7.65^{ab}	7.84^{a}	4.43^{a}	4.66^{a}	80.51^{i}	80.25^{l}
A3	5.67^{cde}	6.01^{ef}	3.00^{cde}	3.11^{de}	90.45^{f}	91.76^{f}
A4	5.88^{cd}	5.23^{g}	2.63^{ef}	2.78^{f}	97.34^{c}	96.78^{d}
A5	5.11^{e}	5.22^{g}	2.65^{ef}	2.76^{f}	100.00^{b}	101.56^{b}
A6	6.00^{c}	6.57^{c}	3.26^{bcd}	3.43^{c}	97.78d	97.22^{c}
A7	6.11^{c}	6.46^{cd}	3.38^{bc}	3.56^{c}	94.67^{d}	93.45^{e}
A8	6.23^{c}	5.27^{g}	3.02^{cde}	3.11^{de}	91.00^{ef}	90.43^{h}
A9	5.00^{e}	5.27^{g}	2.41^{f}	2.55^{g}	91.24^{e}	91.32^{g}
A10	5.00^{e}	5.98^{f}	2.84^{def}	2.99^{e}	102.46^{a}	102.56^{a}
A11	7.84^{a}	7.96^{a}	4.53^{a}	4.78^{a}	83.11^{g}	82.65j
A12	7.10^{b}	7.37^{b}	3.33^{bcd}	3.49^{c}	80.56^{i}	80.10^{i}
A13	6.01^{cd}	6.67^{d}	2.98^{cde}	3.10^{de}	90.67^{ef}	90.56^{h}
A14	5.88^{cd}	6.17^{e}	2.90^{cdef}	3.21^{d}	90.33^{f}	90.45^{h}
A15	6.32c	6.54^{cd}	3.75^{b}	3.83^{b}	91.25^{e}	90.11^{i}
S. E±	0.14	0.13	0.09	0.09	1.00	1.02

Means along the same column with different alphabet are significantly different ($p \leq 0.05$) from each other. A1 Tede oyo 1; A2: Erin Ijesha 1; A3: Budo Bank Ago Amudu; A4: Atisbo Oyo; A5: Arugbadagbe; A6: Tede Oyo 3; A7: Agbado Ekiti; A8: Pepelupe red; A9: Iseyin; A10: Aramoko Ekiti; A11: Ikogusi Ekiti; A12: Pepelupe brick red; A13: Tede oyo 2; A14: Iju Ekiti; A15: Aisegba; S.E: Standard Error. F: Flowering; No: Number

Table 6: Interaction Effect of Evaluated Lima bean in 2022 and 2023

TRT	Pod length (cm)	NSP	50%F
Year			
2022	6.17^{b}	3.24^{b}	90.90^{a}
2023	6.47^{a}	3.49^{a}	90.64^{b}
Landraces			
A1	7.32^{b}	3.70^{bc}	81.87^{i}
A2	7.74^{a}	4.54^{a}	80.38^{j}
A3	5.84^{fe}	3.05^{e}	91.10^{f}
A4	5.11^{g}	2.70^{fg}	97.06^{d}
A5	5.16^{g}	2.70^{fg}	100.28^{b}
A6	6.40^{c}	3.34^{d}	97.50^{c}
A7	6.28^{cd}	3.47^{cd}	94.06^{e}
A8	6.39^{c}	3.06^{e}	90.71^{g}
A9	5.13^{g}	2.48^{g}	91.28^{f}
A10	5.66^{f}	2.91^{ef}	102.51^{a}
A11	7.90^{a}	4.65^{a}	82.88^{h}
A12	7.23^{b}	3.41^{d}	80.33^{j}
A13	6.19^{cd}	3.04^{e}	90.39^{g}
A14	6.02^{de}	3.05^{e}	90.39^{g}
A15	6.43^{c}	3.79^{b}	90.68^{g}
S. E±	0.09	0.06	0.71

Means along the same column with different alphabet are significantly different ($p \leq 0.05$) from each other. A1 Tede oyo 1; A2: Erin Ijesha 1; A3: Budo Bank Ago Amudu; A4: Atisbo Oyo; A5: Arugbadagbe; A6: Tede Oyo 3; A7: Agbado Ekiti; A8: Pepelupe red; A9: Iseyin; A10: Aramoko Ekiti; A11: Ikogusi Ekiti; A12: Pepelupe brick red; A13: Tede oyo 2; A14: Iju Ekiti; A15: Aisegba; S.E: Standard ErrorPL: Pod length, NSP: Number of seed/pods; 50%F: 50% flowering.

Mean 50% flowering, pod length and number of seed

The landraces exhibited significant differences in both growth and yield data in the study. The number of days to 50% flowering varied between 80.51 to 102.46 in 2022 and from 80.25 to 102.56 in 2023 (Table 5). The landrace Atisbo Oyo had the longest pod length in both years (7.12 cm in 2022 and 7.52 cm in 2023), while Arugbadagbe and Aramoko Ekiti had the shortest pod lengths (5.00 cm) in 2022. Landraces Erin Ijesha 1 and Ikogusi Ekiti also exhibited high pod lengths (7.65 cm and 7.84 cm, respectively) in 2023, indicating that these landraces may have superior growth characteristics compared to others. The least landrace to attain 50% flowering in both years of study were those obtained from Aramoko Ekiti and Arugbadabe, respectively. The landraces that flowered earlier were those obtained from Tede Oyo, Erin Ijesha, and Pepelupe Brick Red. The 2023 study revealed that the landraces from Ikogusi Ekiti, Erin Ijesha 1, and Tede Oyo exhibited the longest pod lengths, measuring 7.96 cm, 7.84 cm, and 7.52 cm, respectively. In contrast, landraces from Atisbo Oyo (5.23 cm) and Arugbadagbe (5.32 cm) had the shortest pod lengths (Table 5). In 2023, the length of the lima bean pod (6.47 cm) and the number of seeds/pod (3.49) were considerably greater than in 2022 (pod length: 6.17 cm, seed/pod: 3.24), respectively (Table 5).

Discussion

The presence of multiple nematode species in lima bean fields indicates a complex interaction between the host plant and various parasitic nematodes. The combined effects of *Meloidogyne* spp., *Pratylenchus* spp., and *Helicotylenchus* spp. resulted in notable reductions in lima bean yield, underscoring the importance of managing these nematodes in production. Of the three, *Meloidogyne* spp. were the most prevalent and damaging, causing severe root galls that disrupted water and nutrient flow, leading to stunted growth and significantly reduced yields [10]. In heavily infested lima bean plants, yield losses were particularly severe, with some plants producing fewer pods. *Pratylenchus* spp. also contributed to yield losses, though to a lesser extent, as its root lesions weakened root systems and increased susceptibility to secondary infections, compounding overall plant damage. Although *Helicotylenchus* spp. also contributed to minor yield reductions, by feeding on root epidermal cells and reducing root growth [11]. Given these interactions, adopting integrated nematode management strategies is essential, particularly prioritizing the management of *Meloidogyne* spp. through crop rotation, biological control, and resistant varieties [10].

Furthermore, significant year-to-year variation in lima bean yield parameters suggests that environmental conditions in 2023 were more favorable for production than those in 2022. The study's findings demonstrate that factors such as optimal temperature and moisture in 2023 positively influenced the landraces' performance, leading to higher yields [12]. Early flowering landraces, which complete their reproductive cycle sooner, may better allocate resources during critical growth stages, allowing them to take advantage of favorable climatic conditions and achieve higher yields in drought prone or short-growing seasons. Previous studies support that early flowering landraces allocate more energy towards seed development during favorable periods, increasing pod set and seed size according to Sweta et al. [13] and Agbeleye et al. [14]. The number and size of seeds, as well as pod length, were significant factors in yield variation, with longer pods containing densely packed, large seeds contributing to higher seed yield. Recent advancements in genome-editing technologies, particularly CRISPR/Cas systems, have opened avenues for improving nematode resistance in crops, including lima beans. For example, CRISPR/Cas9 has been used to target genes that nematodes exploit for infection, such as susceptibility genes, to enhance resistance in crops like rice and soybean as reported by Usovsky et al. [15]. These tools enable precise genetic modifications, reducing the reliance on chemical nematicides and enhancing crop resilience. Nematodes such as *Meloidogyne spp.*, *Pratylenchus spp.*, and *Helicotylenchus spp.* significantly reduce lima bean yields through root damage, with environmental factors also playing a critical role. Higher yields were linked to favorable conditions for early-flowering landraces, highlighting the potential of selecting landraces with early flowering traits and longer, seed-filled pods to boost production, especially in regions with short growing seasons or drought stress. Farmers should adopt integrated nematode management practices to reduce nematode populations, while breeders should focus on developing resistant lima bean varieties. Scientists and researchers should also prioritize understanding nematode resistance mechanisms and identifying genotypes suited to diverse agroecological conditions. Collaborative efforts between farmers, breeders, scientists, and policymakers are vital for safeguarding lima bean production and ensuring food security in the face of nematode threats.

Author's Contribution

The research methodology and investigation were carried out by Elufisan Tobi Susan while agronomic data and analysis was carried out by Adebayo Adeyinka Kehinde. Research survey and collection of germplasm was also carried out by Oyedokun Margret.

Acknowledgements

The authors wish to express their gratitude to all the field staff at the Institute of Agricultural Research and Training for their support during the field trial.

Declaration of Competing Interest

The authors declare that there are no known conflicts of interest related to this publication.

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