Nigeria Journal of Plant Breeding
Volume 3(1), pages 41 - 49, January 2026
ISSN: 2814-3531

https://pbanjournal.org/

PLANT BREEDERS ASSOCIATION OF NIGERIA

Full Length Research

COMPARATIVE PERFORMANCE IN GROWTH, FLOWERING, POLLEN STAINABILITY AND FRUITING IN EGGPLANT (*Solanum melongena* L.)

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Received 28th December, 2025; Accepted 7th January, 2026

ABSTRACT The study assessed growth, flowering behaviour, pollen stainability, and fruiting performance of four eggplant genotypes—NHEP 0073, NHEP 0093, European Merdan 465 F_1 hybrid, and a farmer-selected local genotype- under high rainfall and humid conditions in Port Harcourt, Rivers State, Nigeria. The experiment was conducted at the Department of Plant Science and Biotechnology, Rivers State University, using a Completely Randomized Design (CRD) with six replications. Seedlings were raised for approximately 35 days and transplanted singly into perforated polypropylene woven bags containing 20 kg of loamy soil amended with 200 g of poultry manure. Data were collected on vegetative growth traits, reproductive traits, pollen stainability, reproductive efficiency, and selected qualitative characters. Data collected were subjected to analysis of variance. The results revealed highly significant ($p \leq 0.05$) differences among the genotypes for all measured traits, indicating the presence of substantial genetic variability. The farmer-selected local genotype and the European Merdan 465 F_1 hybrid consistently exhibited superior vegetative vigour, higher pollen stainability, enhanced flower-to-fruit conversion efficiency, and significantly greater fruit yield when compared with NHEP 0073 and NHEP 0093. Observed variation in qualitative traits further demonstrated exploitable genetic diversity within the evaluated germplasm. The performance of the local genotype suggested the presence of favourable adaptive alleles conferring tolerance to high humidity and rainfall, while the superior yield of the F_1 hybrid reflects the contribution of heterosis. These genotypes therefore possess high breeding value and can be strategically utilized as parental materials in selection and hybridization programmes aimed at developing climate-resilient, high-yielding eggplant varieties for humid tropical agro-ecologies of southern Nigeria.

Keywords: Flower abscission, Flower bud, Genetic variability, Pollen stainability, *Solanum melongena*..

INTRODUCTION

Eggplant (*Solanum melongena* L.), commonly referred to as brinjal in Asia and aubergine in Europe, is a member of the family Solanaceae and is widely cultivated across southern Europe, the southern United States, Asia, the Mediterranean region, and Sub-Saharan Africa (Mat-Sulaiman *et al*., 2020). Although the crop is predominantly grown in arid and semi-arid environments, eggplant serves as an important vegetable crop globally, contributing significantly to household nutrition, income generation, food diversity, and food security, particularly among resource-poor smallholder farmers

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in developing countries (Caruso *et al*., 2017). Beyond its use as leafy and fruit vegetable, some eggplant cultivars are utilized as natural dyes and food colourants due to their rich pigment composition (Vidana Gamage *et al*., 2022). Eggplant exhibits remarkable genetic and phenotypic diversity, reflected in wide variation in fruit colour: white, yellow, green, brown, purple, and variegated forms of these colours, spotted and pigmented to nearly black, etc.; fruit size and shape: egg-shaped, round, oblong, elongated curved club-shaped, oval, long club-shaped, etc. In addition, it has varied leaf forms: entire, dentate, sinuate, etc., leaf blade lobbing from very weak, intermediate to very strong and leaf blade tip angle from very acute, intermediate to very obtuse, etc.; growth habit, yield potential, and resistance to biotic and abiotic stresses (Tripathy *et al*., 2025; Yadav *et al*., 2025). The species also displays heterostyly, characterized by flowers with long, medium, quasi-short, and short styles, which influences pollination efficiency and fruit set (Raja, 2021; Khaleghi *et al*., 2021a). In addition, eggplant is nutritionally rich, containing carbohydrates, proteins, dietary fibre, essential minerals, vitamins, and diverse phytochemicals including anthocyanins, flavonoids, phenolic acids, and other antioxidant compounds that confer significant health and medicinal benefits (Henry *et al*., 2022). Despite its importance, the adaptation and performance of eggplant under the humid, high-rainfall conditions of the Niger Delta region of Nigeria remain poorly documented. Port Harcourt, Rivers State, is characterized by annual rainfall exceeding 2300 mm and consistently high relative humidity (70–85%), conditions that may predispose eggplant to flooding, fungal diseases, insect infestations, and impaired reproductive processes, particularly reduced pollen viability (Hautea *et al*., 2016; Mustroph, 2018). Eggplant growth is sensitive to both temperature and moisture extremes; while low temperatures (<16 °C) inhibit vegetative growth, excessive rainfall and soil moisture adversely affect flowering, fruit set, and yield (Adamczewska-Sowińska *et al*., 2016). Pollen viability is a critical determinant of reproductive success and fruit yield in eggplant, especially under humid conditions where rainfall can disrupt pollination processes. High pollen viability is essential for effective hybridization, fruit set, and yield improvement, making pollen studies indispensable in breeding programmes (Biratu, 2018; Khaleghi *et al*., 2021b). Previous studies have reported wide variation in eggplant pollen viability depending on genotype, environmental conditions, and staining methods (Skrzypkowski *et al*., 2023). Both excessively low and high relative humidity have been shown to reduce pollen germination in eggplant, further emphasizing the need to screen genotypes for pollen stainability as a proxy for reproductive fitness in humid environments (Kowalska, 2008). Most existing eggplant breeding efforts have focused on adaptation to dry or drought-prone environments (Gramazio *et al*., 2017), leaving a critical gap in the development of varieties suited to high-rainfall, high-humidity agro-ecologies. Therefore, the objective of the study was to determine systematic evaluation of growth, flowering behaviour, pollen stainability, and fruiting performance of diverse eggplant genotypes under the humid conditions of Port Harcourt.

MATERIALS AND METHODS

This research was carried out from March to September 2024 on the experimental plot of Plant Science and Biotechnology Department, Rivers State University, Port Harcourt, Nigeria (Latitude 4.804°N, Longitude 6.980°E). The region is characterized by high annual rainfall (>2300 mm), high relative humidity (80–95%), and sandy-loam soil. Four genotypes of eggplants were sourced as follows: two genotypes NHEP 0073 and NHEP 0093 from National Institute of Horticultural Research and Training (NIHORT), Ibadan, Oyo State, Nigeria; one exotic European Merdan 465 F_1 hybrid was gotten from Agriseed Ltd, Technisem, France and a farmer's local genotype obtained in Port Harcourt, Rivers State, Nigeria, were used.

Seeds of four genotypes were sown at 20 seeds per perforated transparent plastic nursery tray (16 × 10 × 5 cm) containing 425 g of sandy loam soil and watered as required. Each genotype was raised separately and maintained for three weeks for germination. Uniform seedlings were transplanted singly into perforated polyethylene sachets (15 × 11.5 cm) filled with 200 g of sandy loam soil and grown for two weeks. Thereafter, one seedling was transplanted into perforated Bagco polypropylene woven bags (55 × 45 cm) filled to three-quarters capacity with 20 kg of sandy loam soil amended with 200 g of poultry manure. The experiment was laid out in a Completely Randomized Design (CRD) with six replications. Routine agronomic practices, including watering, weeding, earthing-up, and staking, were carried out.

At anthesis, two flowers from a single plant of each of the genotypes were used to compare pollen using the staining method, with nuclear dye, 2% aceto-carmine. Pollen grains were harvested from anthers between 8:00-9.00 am when flowers were completely open (Laxman *et al*., 2021) with a dissecting needle to disrupt the anthers and release the pollen grains onto a microscope slide. The pollen grains were spread on microscope slides, then suspended in a drop of 1:1 aceto-carmine and glycerol and slides covered with slips, edges of the slips were sealed with transparent nail polish. After 10 minutes staining at room temperature, the prepared slides were observed using a light compound microscope (Olympus BX41 with DP12 camera). For each of four flowers 100 pollen grains were counted. Stained, uniform pollen grains were considered viable, while unstained, irregular pollen were considered non-viable. Pollen viability was declared in form of a percentage of viable pollen (Skrzypkowski *et al*., 2023). The viability percentage was calculated from the mean of four microscopic counts as follows:

$$\text{\% Pollen viability} = \frac{\text{N0 of pollen grains stained}}{\text{Total no.of observed pollen grains}} X100\%$$

Data were collected on leaf area, leaves/plant, plant height, stem girth, flower buds/plant, days to flowering, flowers/plant, and fruits/plant. Others were percentage pollen stainability, percentage of flower buds that formed flowers, percentage flowers that formed fruits, shape of leaves and shape and colour of fruits. Data were subjected to ANOVA using the general linear model and the means were separated using least significant difference (LSD) at 5% level of probability to draw statistical conclusions.

RESULTS AND DISCUSSION

Vegetative Traits of the Four Eggplant Genotypes

The vegetative performance of the four eggplant genotypes presented in Table 1 revealed that significant differences ($p \leq 0.05$) were observed among the genotypes for all measured vegetative traits, indicating the presence of substantial genetic variability exploitable for selection and breeding. Plant height varied significantly among the genotypes, in which the European Merdan 465 F_1 hybrid recorded the tallest plants (48.0 cm). This was followed by the farmer's local genotype (29.9 cm), which was significantly taller than NHEP 0073 (20.9 cm) but comparable to NHEP 0093 (26.4 cm). Increased plant height in the F_1 hybrid suggested the expression of heterosis, which is often associated with enhanced vegetative growth and improved assimilate production for reproductive development. Similarly, stem girth differed significantly among the genotypes, in which European Merdan 465 F_1 hybrid recorded the thickest stem (3.3 cm), significantly exceeding those of the farmer's local genotype (2.8 cm) and NHEP 0073 (2.7 cm), but not NHEP 0093 (3.0 cm). A thicker stem is a desirable agronomic trait as it enhances mechanical strength and lodging resistance, particularly under humid and high-rainfall conditions, and supports higher fruit load. The superior performance of the F_1 hybrid for plant height and stem girth corroborates earlier reports that hybrid eggplant cultivars often exhibit vigorous vegetative growth to sustain large or multiple fruits (Chinthagunti *et al*., 2018). The farmer's local genotype recorded the highest number of leaves per plant (14.5), significantly exceeding those of NHEP 0093 (10.5), the European Merdan 465 F_1 hybrid (9.3), and NHEP 0073 (7.0). In contrast, this genotype had the smallest leaf area (39.7 cm²), whereas the remaining genotypes exhibited significantly larger and comparable leaf areas. This contrasting leaf architecture suggests a genetically regulated adaptive strategy in the local genotype, whereby increased leaf number compensates for reduced leaf size to maximize light interception while minimizing self-shading. Such a canopy structure may confer an advantage under prolonged cloudy and humid conditions typical of the study environment. The observed variation in vegetative traits among the genotypes aligns with previous reports of significant genetic differences in eggplant for plant height, leaf number, leaf area, and stem girth (Pandiyaraj *et al*., 2025; Tripathy *et al*., 2025). From a breeding perspective, the strong vegetative vigour of the European Merdan 465 F_1 hybrid highlights its potential as a donor of vigour-related traits, while the adaptive leaf architecture of the farmer's local genotype accentuates its value as a parent for improving canopy efficiency and environmental adaptation in humid tropical breeding programmes.

Table 1: Vegetative Traits of the Four Eggplant Genotypes, Port Harcourt, Rivers State, Nigeria

Eggplant Genotypes	Plant Height (cm)	Plant Girth (cm)	Number of Leaves/ plant	Leaf area (cm^2)
Merdan F_1 Hybrid	48.0	3.3	9.3	150.4
Farmer's Local Genotype	29.9	2.8	14.5	39.7
NHEP 0093	26.4	3.0	10.5	149.4
NHEP 0073	20.9	2.7	7.0	146.7
LSD (0.05)	6.48	0.50	4.12	66.03

Floral and Fruit Characteristics of the Four Eggplant Genotypes

The flowering and fruiting characteristics of the four eggplant genotypes presented in Table 2 revealed significant ($p \leq 0.05$) differences among the genotypes for all reproductive traits measured, indicating marked genetic variation in flowering behaviour, reproductive efficiency, and fruiting capacity. The number of flower buds per plant varied significantly, with NHEP 0073 producing the lowest number (8.0), while the European Merdan 465 F_1 hybrid recorded the highest (30.0), which was significantly greater than that of the farmer's local genotype (24.0) but comparable to NHEP 0093 (27.0). The high flower bud production of the F_1 hybrid reflected an enhanced floral initiation which often associated with heterosis, although high bud number did not necessarily translate into superior fruit set. Significant differences were also observed in days to flowering. The farmer's local genotype flowered significantly later (102.0 days) than NHEP 0073 (69.3 days), but did not differ significantly from the European Merdan 465 F_1 hybrid (85.8 days) and NHEP 0093 (77.3 days). Variation in flowering time is largely genetically controlled and may be influenced by differences in endogenous phytohormone levels, particularly gibberellins (Chinthagunti *et al*., 2018). Although earliness is a desirable breeding objective in vegetable crops due to its economic and agronomic advantages, early flowering alone does not guarantee higher yield, as reproductive success is strongly dependent on flower retention and fruit set. Similar genotypic variation in flowering time has been reported in eggplant by Sahu *et al*. (2022), and Pandiyaraj *et al*. (2025). The number of flowers per plant differed significantly among genotypes, with the farmer's local genotype producing the highest number (17.0), while NHEP 0073 recorded the lowest (3.0). The European Merdan 465 F_1 hybrid (9.0) and NHEP 0093 (11.0) were statistically similar. The proportion of flower buds that developed into flowers was significantly highest in the farmer's local genotype (70.8%), whereas NHEP 0073 (37.5%), NHEP 0093 (40.7%), and the European Merdan 465 F_1 hybrid (30.0%) exhibited low conversion rates (<50%). This indicates a lower rate of flower bud abscission in the local genotype, suggesting superior reproductive stability and better adaptation to the humid environment. Similar observations linking reduced floral abscission to environmental adaptation have been reported by Sahu *et al*. (2022) and Pandiyaraj *et al*. (2025). Fruit production followed a similar trend, with the farmer's local genotype recording the highest number of fruits per plant (4.0), significantly exceeding the European Merdan 465 F_1 hybrid (2.0), NHEP 0073 (0.7), and NHEP 0093 (0.5). These findings are consistent with earlier reports of significant genotypic differences in fruit number in eggplant (Hanwate *et al*., 2025; Pandiyaraj *et al*., 2025). Although overall flower-to-fruit conversion was low across genotypes, the farmer's local genotype recorded the highest percentage (23.5%), comparable to NHEP 0073 (23.3%) and the European Merdan 465 F_1 hybrid (22.2%), but significantly higher than NHEP 0093 (4.5%). Low fruit set in eggplant has been widely reported and attributed to high rates of flower abscission and fruit drop (Sekara and Bieniasz, 2008; Khaleghi *et al*., 2021a; 2021b). The poor reproductive performance of NHEP 0073 and NHEP 0093 suggests limited adaptation to the humid, high-rainfall conditions of the study environment, possibly due to their breeding history in relatively drier agro-ecologies (Chinthagunti *et al*., 2018). High floral abortion in eggplant has been associated with inadequate pollination, poor assimilate partitioning, and hormonal imbalances regulating fruit development (Pohl *et al*., 2019). The superior reproductive efficiency of the farmer's local genotype emphasizes the importance of local adaptation in breeding for humid environments. Significant variation was also observed in qualitative traits such as leaf morphology and fruit colour (Plate 1), further confirming the presence of exploitable genetic diversity among the genotypes. From a breeding standpoint, the farmer's local genotype represents a valuable source of adaptive and reproductive efficiency traits, while the European Merdan 465 F_1 hybrid provides vigour-related attributes. Their complementary strengths highlight their potential utility as parental materials in hybridization and selection programmes aimed at improving eggplant productivity under humid tropical conditions.

Table 2: Floral and Fruit Characteristics of the Four Eggplant Genotypes, Port Harcourt, Rivers State, Nigeria

Eggplant Genotypes	Flower Buds/ plant	Days to Flowering	Flowers/ plant	% of Buds that formed Flowers	% of Flowers that formed Fruits	Fruits/ plant
Merdan F_1 Hybrid	30.0	85.8	9.0	30.0	22.2	2.0
Farmer's Local Genotype	24.0	102.0	17.0	70.8	23.5	4.0
NHEP 0093	27.0	77.3	11.0	40.7	4.5	0.5
NHEP 0073	8.0	69.3	3.0	37.5	23.3	0.7
LSD (0.05)	3.35	24.3	2.39	3.51	1.47	1.61

Pollen Stainability

The results of pollen stainability assessed using aceto-carmine staining are presented in Figure 1, while representative stained pollen grains are shown in Plate 3. Pollen stainability, which provides an estimate of potential pollen viability and male fertility, differed significantly ($p \leq 0.05$) among the four eggplant genotypes. The highest pollen stainability was recorded in NHEP 0073 (95%), followed by NHEP 0093 (91%), both of which were significantly higher than the farmer's local genotype (80%). The European Merdan 465 F_1 hybrid recorded intermediate pollen stainability (85%), which was significantly lower than NHEP 0073 but statistically comparable to NHEP 0093. The significant genotypic differences observed in pollen stainability are consistent with earlier reports in other crops, where pollen viability varied markedly among cultivars and was influenced by both genetic constitution and staining methods (Skrzypkowski *et al*., 2023; Das *et al*., 2025). Similar variability in pollen viability has also been documented in eggplant and related Solanaceous crops, stressing the importance of pollen assessment in reproductive and breeding studies. Interestingly, genotypes with the highest pollen stainability (NHEP 0073 and NHEP 0093) produced the lowest number of fruits per plant, whereas the farmer's local genotype, despite having comparatively lower pollen stainability, recorded superior fruit set. This apparent disconnect indicates that high pollen stainability alone does not necessarily translate into successful fertilization or fruit development under field conditions. Although pollen stainability is a useful indicator of male fertility, actual reproductive success depends on multiple interacting factors, including effective pollen germination, pollen tube growth, stigma receptivity, ovule viability, and assimilate availability (Laxman *et al*., 2021; Das *et al*., 2025). The performance of pollen is strongly influenced by both intrinsic genetic factors and environmental conditions such as temperature, relative humidity, nutritional status, and hormonal balance of the plant (Harel *et al*., 2014; Skrzypkowski *et al*., 2023). In humid tropical environments, excessive moisture may impair pollen germination and pollen tube growth despite high stainability, leading to poor fruit set. Therefore, low fruit production in NHEP 0073 and NHEP 0093 cannot be attributed solely to pollen in viability but rather to a complex interaction of reproductive and environmental constraints. From a breeding perspective, these results highlight the importance of evaluating pollen performance in conjunction with flowering behaviour and fruit set, rather than relying on pollen stainability alone. Genotypes such as NHEP 0073 and NHEP 0093 may serve as useful donors of high pollen viability traits in hybridization programmes, while the farmer's local genotype represents a valuable source of genes for reproductive stability and fruit set under humid conditions. Integrating these complementary traits through targeted hybridization could enhance eggplant productivity and adaptability in high-rainfall agro-ecologies.

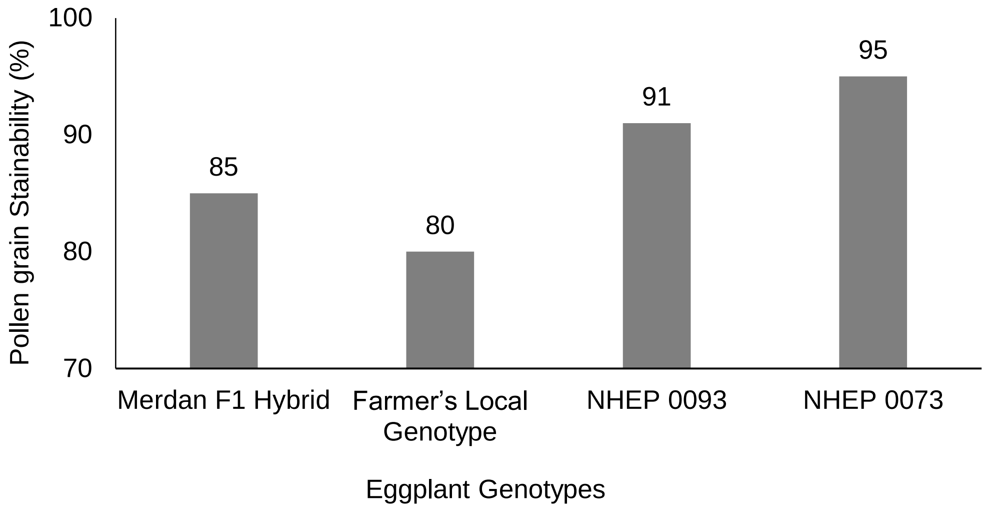
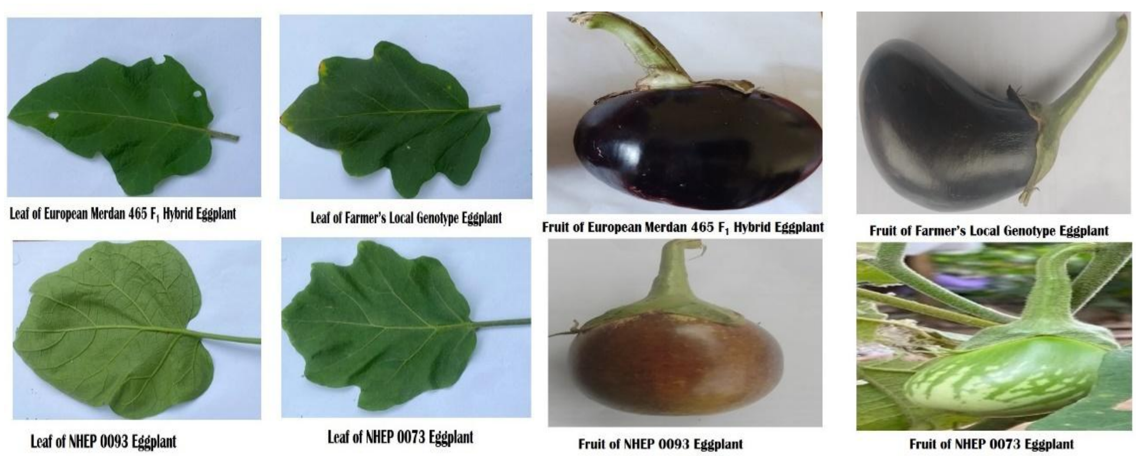


Figure 1. Percentage Pollen grain Stainability of the Four Eggplant Genotypes



(a) (b)

Plate 1. Leaves and Fruits of the Four Eggplant Genotypes.

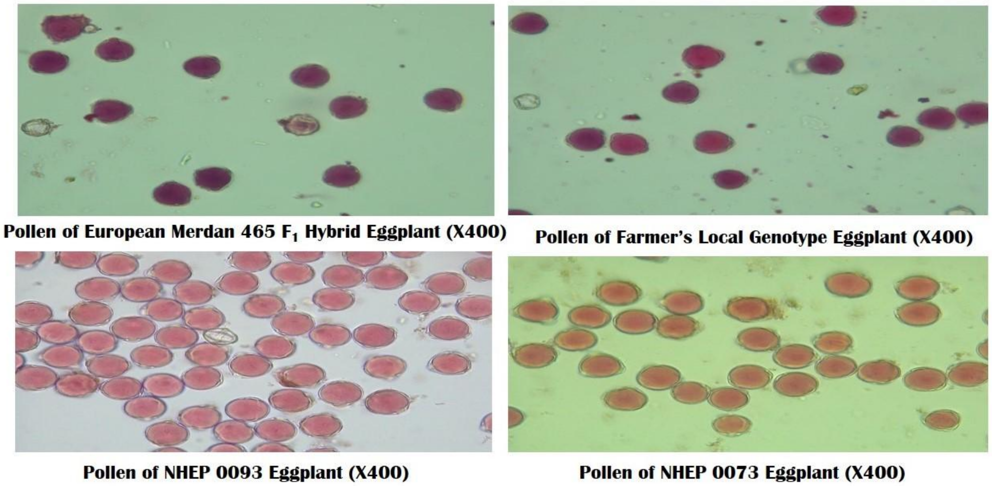


Plate 2. Acetocarmine Stained Pollen of the Four Eggplant (*Solanum melongena*) Genotypes

CONCLUSION

This study demonstrated that the farmer-selected local genotype and the European Merdan 465 F_1 hybrid exhibited superior overall performance compared with NHEP 0073 and NHEP 0093 under the high-rainfall and humid conditions of Port Harcourt. Their enhanced vegetative vigour, improved reproductive efficiency, and higher fruit yield indicate better adaptation to the prevailing agro-ecological conditions, supporting their suitability for use as leafy, fruit, or dual-purpose vegetable types in the region. High levels of flower bud abscission, flower drop, and generally low fruit set were observed across the genotypes, confirming that reproductive instability remains a major constraint to eggplant production in humid environments. However, the contrasting responses of the genotypes for flowering behaviour, pollen stainability, and fruit set revealed the presence of substantial genetic variability for both vegetative and reproductive traits. This variability represents a valuable resource for selection and genetic improvement. The farmer's local genotype demonstrated superior reproductive stability and fruit set, suggesting the presence of favourable adaptive alleles conferring tolerance to excessive rainfall and high relative humidity. In contrast, the European Merdan 465 F_1 hybrid expressed strong vegetative vigour and floral initiation, indicative of heterotic effects. Meanwhile, NHEP 0073 and NHEP 0093, despite high pollen stainability, showed poor fruiting performance, highlighting the need to consider whole-plant reproductive efficiency rather than pollen viability alone in breeding decisions. Overall, the findings underscore the importance of utilizing locally adapted germplasm alongside elite hybrids in eggplant breeding programmes. Strategic hybridization and selection, combining adaptive traits, reproductive efficiency, and yield potential will be critical for developing climate-resilient, high-yielding eggplant varieties suited to humid tropical agro-ecologies of southern Nigeria.

Conflicts of interest

Authors do not have any conflicts of interest.

Acknowledgement

Two eggplant genotypes, NHEP 0073 and NHEP 0093 were obtained from the National Institute of Horticultural Research and Training (NIHORT), Ibadan, Oyo state.

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HOW TO CITE THIS ARTICLE:

Wilson, V and Paul, S. (2026).. Comparative performance in growth, flowering, pollen stainability and fruiting in eggplant (*solanum melongena* l.). Nigeria Journal Of Plant Breeding (https://pbanjournal.org/), 3(1), 41-49. ISSN: 2814-3531