



INFLUENCE OF HARVEST MATURITY STAGE AND PACKAGING MATERIAL ON SEED GERMINABILITY AND VIGOUR OF “SHOMBO” PEPPER (*Capsicum annuum* L.) IN LAPAI, NIGER STATE, SOUTHERN GUINEA SAVANNAH, NIGERIA

¹Stephen, Yage Deborah., ²Polycarp, Ozobia Anyaegbu., ¹Usman, Habiba, ³Dennis, Iorkor., , ¹Yahaya, Ibrahim., ⁴Jalal, Maihula., ¹Sale, Musa Majinga., ¹Ndana, Tetengi Kedigi., ¹Aliyu, Danjuma Aliyu.

¹Department of Biological Science, Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria

²Department of Crop Science, University of Abuja, Nigeria

³Department of Plant Breeding and Seed Science, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria

⁴Department of Agriculture, Ministry of Agriculture and Food Security, Abuja, Nigeria

<https://doi.org/10.70118/ajaas.032606010.03>

ABSTRACT

A field and laboratory experiment was conducted at the Teaching and Research Farm and Biological Science Laboratory of Ibrahim Badamasi Babangida University, Lapai, Niger State, to determine the influence of harvest maturity stage and packaging material on seed germinability and vigour of “shombo” pepper. Seedlings of “Shombo” were raised in the nursery and transplanted to the field. Tagging of flowers was done as they opened, and the date of opening (termed anthesis) was recorded on each tag. As many flowers as possible were date-tagged for the pepper variety (Shombo). Fruits that developed from the tagged flowers were harvested at the mature green stage at 46 days after anthesis (DAA), mature half red ripe at 49 (DAA) and mature full red ripe at 52 (DAA). The extracted seeds from the harvested fruits were dried to a safe moisture content and packaged separately in labeled aluminium foil and cloth bags and stored at room temperature for a period of 6 months, after which a germination test was conducted. Seed quality characteristics measured were seed leachate electro-conductivity (SLE), seed moisture content (SMC), seed germination index (SGI), seedling plumule length (SPL), and seedling vigour index (SVI). The results from Analysis of Variance (ANOVA) revealed that harvest stage significantly influenced all seed quality parameters, with seeds harvested at the mature full red ripe stage (52 DAA) exhibiting optimal quality attributes. Packaging material also had a significant effect, with aluminium foil packaging outperforming cloth bag packaging in maintaining seed quality and viability.

Key words: packaging material, germinability, seed vigour, harvest maturity, shombo pepper

INTRODUCTION

Capsicum annuum, commonly referred to as pepper, is believed to have originated in the tropical zones of Central and South America (Clement *et al.*, 2010). Following its introduction to Europe during early exploration periods, the crop spread rapidly and is now cultivated globally. Its adaptability to a variety of soil types and climatic conditions has contributed to its widespread production across continents. (Kwon *et al.*, 2023). With significant production hubs in Asia, Europe, and the Americas, pepper is widely grown around the world (Tripodi *et al.*, 2021). It is a versatile crop for farmers because it can be grown in a range of climates and soil types (Clifford *et al.*, 2024). Pepper is a widely grown and economically significant crop worldwide, with "Shombo" pepper being a popular type in many areas including Nigeria (Guaguiyi *et al.*, 2025).

Vietnam is the world's largest pepper producer (257,427 tons), followed by Brazil (126,548 tons); Burkina Faso leads Africa in pepper output (73,836 tons in 2023), placing third globally (FAOSTAT, 2025).

Seeds play a crucial role in the production of pepper, and their quality significantly impacts crop

performance (Dobón-Suárez *et al.*, 2025). Costa *et al.* (2021) reported that vigor and seed germinability are crucial elements that affect pepper performance. Harvest maturity stage and packaging materials are critical factors that can influence seed quality, germinability, and vigor Shereen *et al.*, (2025). The physiological quality of seeds can be influenced by the harvest maturity stage; seeds collected at the ideal stage show greater vigor and germination rates (Tetteh *et al.*, 2021). Similarly,

RajKumar *et al.* (2021) packaging materials can impact seed quality during storage by controlling moisture and temperature. Despite the importance of these factors, there is limited research on the influence of harvest maturity stage and packaging materials on seed germinability and vigor of "Shombo" pepper. This study investigated the effects of different harvest maturity stages and packaging materials on seed germinability and vigour of "Shombo" pepper. The findings provide valuable insights into optimal harvest and storage practices for improving seed quality, which is one of the major factors influencing successful crop production.

MATERIALS AND METHODS

A field and laboratory work was conducted at the Teaching and Research Farm and Biological Science laboratory of Ibrahim Badamasi Babangida University, Lapai, Niger State, Nigeria which lies between the latitude of 9.0674°N and longitude 6.5618°E during the 2024-2025 farming season. Seeds of a particular sweet pepper variety called "Shombo" were utilized as the planting material, and were gotten from local growers in Lapai and the surrounding area.

Nursery establishment

A 2 m × 2 m nursery bed was prepared and leveled prior to sowing. Seeds were placed in shallow furrows and covered with a thin layer of soil. The bed was mulched with dried grass to conserve moisture until germination, after which the mulch was removed to improve aeration and exposure to light to allow for hardening of the seedlings before transplanting to the permanent field.

Field Preparation and Transplanting

The field was cleared manually using cutlass and beds were made manually using a big hoe. Seedlings were moved to the field once they produced four to five true leaves, roughly 4–5 weeks after sowing (Ndagana *et al.*, 2022). Transplanting took place in the late afternoon to reduce heat stress and allow the seedlings to establish more easily. Only healthy and strong seedlings were transplanted at a recommended spacing of 45cm x 60cm. The transplanting was done in the evening hours to minimize transplanting shock. After transplanting, the seedlings were watered to prevent moisture stress and to bind the soil particles together with the roots so that nutrients could be readily drawn by the roots of the seedlings.

Fertilizer application

A total fertilizer dose of 120 kg N, 60 kg P_2O_5 , and 60 kg K_2O ha^{-1} was used. Half of the nitrogen and all of the phosphorus and potassium were applied at three weeks after transplanting using NPK 15–15–15. The remaining nitrogen was supplied in two equal portions at six and nine weeks after transplanting through urea source (Hartono *et al.*, 2022).

Insect Pest Control

Sharp-shooter insecticide which has a combination of Profenofos 40 % + Cypermethrin as active ingredients at the rate of 1.5 L ha^{-1} was used to control insects like thrips, aphids, whiteflies and caterpillars. (Esther *et al.*, 2021).

Flower Tagging, Harvesting and post-harvest handling of fruits and seeds

Tagging of the flower was done as it opened,

and the date of opening (termed anthesis) was recorded on each tag. As many flowers as possible were date-tagged for the pepper variety (Shombo). Fruits that developed from the tagged flowers were harvested at the mature green stage at 46 (DAA), mature half red ripe at 49 (DAA) and mature full red ripe at 52 (DAA). Seeds were then extracted from the fruits using a clean knife and dried to a safe moisture content of 11–13%. 100 grams of dried seed from each harvest stage were packaged separately in labeled aluminum foil and cloth bags in triplicate and stored at room temperature for a period of 6 months.

Experimental procedure and design

The germination response of pepper seeds harvested at different harvest maturity stages and stored in different packaging materials was determined using 100 seeds from each treatment combination in three replicates. Seeds from each treatment combination were counted and placed on moistened germination paper in Petri dishes arranged in a completely randomized design (CRD). Incubation was done at a room temperature of about 30°C for 14 days. Germination count was done for each day for a period of 14 days, after which the following were determined:

* Seed Leachate Electro-conductivity (SLE)

50 seeds of each of “shombo” and three fruit harvest maturity stages were counted in two replicates. The seeds were put into beakers and each beaker contained 30 milliliters (ml) of distilled water. The seeds were thoroughly immersed in the distilled water for 24 hours. The solution in the seed/distilled water mixture was decanted,

leaving the solution only. In accordance with Ramos *et al.* (2012), a Jenway DDS-307 conductivity meter was subsequently inserted in the decanted solution in each beaker to measure the conductivity of the seed electrolyte. The mean value was recorded in microsiemens per centimeter ($\mu\text{S}/\text{cm}$). This was done before the germination test.

$$SMC = \frac{\text{Weight of wet seeds} - \text{Weight of oven dried seeds}}{\text{Weight of wet seeds}} \times 100 \quad (\text{ISTA. 2018})$$

* Seed Germination Percentage (SGP)

Seed germination was tested at 6 months after storage. This was done by counting four replicates of 50 seeds in each of the

* Seed Moisture Content (SMC)

Seed moisture content was measured using the high-temperature oven-drying procedure, which involves drying samples at 130°C for one hour, following ISTA guidelines. The moisture percentage was calculated based on the weight loss after drying as indicated in the formula below:

treatment combinations and placing it in Petri dishes with water-moistened germination paper. Germination counts were from the first day to the 14th after sowing (DAS):

$$SGP = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

* Seedling Plumule Length (SPL)

The seedling plumule length was determined on the 14th DAS. This was done by randomly selecting five seedlings and the plumule in each treatment and measured in mm.

* Seedling Vigor Index (SVI)

Seedling vigour index (SVI) was computed as the product of the germination percentage and the average seedling plumule length, in accordance with established vigour assessment procedures of Abdulbaki and Anderson, (1979).

RESULT AND DISCUSSION

Table 1 showed the mean squares from the analysis of variance for the "Shombo" seed quality parameters. Seed leachate electro-

conductivity (SLE), seed moisture content (SMC), seed germination percentage (SGP), seed germination index (SGI), seedling plumule length (SPL), and seedling vigour index (SVI) were all significantly influenced by harvest stage ($p \leq 0.01$), as indicated in the table. On the contrary, packaging material was significant ($p \leq 0.05$) for SLE, SGI, SPL, and SVI and very significant ($p \leq 0.01$) for SGP and SMC. Similarly, Harvest Stage x Packaging Material interaction was highly significant ($p \leq 0.01$) for SLE, SMC, SGP, SGI, SPL and SVI. The three maturity levels of the shombo fruits at harvest and the two types of packages used during storage are shown in Plates 1 and 2.



Plate 1: The three maturity levels of the shombo fruits at harvest



Plate 2: Two types of packaging used during the storage of shombo seeds

Table 1: Mean Squares from Analysis of Variance for Seed Quality Attributes of “Shombo”

SOV	DF	SLE (μ S/cm)	SMC (%)	SGP	SGI	SPL (cm)	SVI
Replication	2	71.90	611.80	281.60	45.08	60.65	112.53
Harvest Stage	2	53.12**	70.11**	56.72**	11.21**	67.09**	212.45**
Packaging Material	1	74.13*	912.68**	541.12**	26.45*	351.67*	63.61*
Error	12	90.62	12.67	33.11	27.45	35.41	36.71
Total	17						

KEY

SGP = seed germination percentage

SVI = seedling vigour index

DAA = days after anthesis

SMC = seed moisture content

SGI = seed germination index

SLE = seed leachate electro-conductivity

SPL = seedling plumule length

The mean effect of harvest stage on seed quality attributes of “shombo” is indicated in Table 2. The result showed that fruits harvested at the mature full red ripe stage, 52 days after anthesis (DAA) recorded the highest SLE (96.78), which was significantly higher than the mature half red ripe stage, 49 DAA (87.98) and the mature green stage, 46 DAA (67.78). A similar trend was observed for SGP, SGI, SPL and SVI. SMC on the other hand, was highest in the mature green stage 46 DAA (15.78), although not significantly different from the mature half red ripe stage 49 DAA (14.56), it was significantly higher than the mature

full red ripe stage 52 DAA (12.67). SLE of seeds was significantly higher in cloth bag packaging (68.89) compared to seeds in aluminium foil packaging (54.22). Similarly, SMC was significantly higher in cloth bag packaging (14.31) than aluminium foil packaging (12.87). On the contrary, SGP was significantly higher in seeds packaged in aluminum foil (93.87) compared to cloth bag packaged seeds (71.90). A similar trend was observed in SGI, SPL and SVI in which aluminum packaging was consistently superior to cloth bag packaging.

Table 2: Mean Effect of Harvest Stage and Packaging Material on Seed Quality Attributes of “Shombo”

Harvest Stage (DAA)	SLE ($\mu\text{S}/\text{cm}$)	SMC (%)	SGP	SGI	SPL (cm)	SVI
Mature green stage 46 (DAA)	96.78a	15.78a	50.67c	5.76c	2.57c	190.78c
Mature half red ripe 49 (DAA)	87.98b	14.56a	70.41b	7.56b	3.23b	297.50b
Mature full red ripe 52 (DAA)	67.78c	12.67b	97.45a	9.67a	4.75a	467.34a
Packaging Materials						
Aluminum Foil	54.22b	12.87b	93.87a	8.63a	4.87a	432.22a
Cloth Bag	68.89a	14.31a	71.90b	5.67b	3.11b	301.63b

*Means with the same letter(s) within a column are not significantly different

KEY

SGP = seed germination percentage

SVI = seedling vigour index

DAA = days after anthesis

SLE = seedling plumule length

SGI = seed germination index

SMC = seed moisture content

SGP = seed germination percentage

Table 3 shows the Harvest stage x Packaging material interaction effect on seed quality attributes of “Shombo”. The table indicated that the interaction between harvest maturity stage and packaging material significantly influenced all measured seed quality parameters of *Capsicum frutescens* (“Shombo”) (Table 3). Under aluminum foil packaging, seed quality improved progressively with increasing fruit maturity. Seeds harvested at the full red ripe stage (52 DAA) and stored in aluminum foil exhibited the highest germination percentage (97.54%), germination index (9.23), seedling plumule length (4.98 cm) and seedling vigour index (491.23). These values were significantly superior to those obtained at the mature green stage (46 DAA).

A similar trend was observed in seeds stored in cloth bags; however, values across all maturity stages were consistently lower when compared with aluminum foil. For example, full red ripe seeds packaged in cloth bags

recorded 71.90% germination, an SGI of 6.78, plumule length of 3.06 cm and a SVI of 375.57— all significantly lower than corresponding values under aluminum foil packaging. The relatively higher electro-conductivity (76.67 $\mu\text{S}/\text{cm}$) and moisture content (12.89%) in cloth-bag treatments suggest higher membrane leakage and suboptimal drying, which could be attributed to the porous nature of the material.

Across maturity stages, the 48–52 DAA (half-red to full-red stage) consistently produced seeds with superior physiological quality under both packaging conditions, confirming that seed maturity at harvest is a primary determinant of viability and vigour. However, the marked differences between packaging materials highlight the importance of the storage environment. Aluminum foil, being moisture-proof and non-permeable, provided a more stable microenvironment, leading to reduced seed deterioration and enhanced germination attributes.

Table 3: Harvest Stage x Packaging Material Interaction Effect on Seed Quality Attributes of “Shombo”

Packaging Material x Harvest Stage	SLE (μS/cm)	SMC (%)	SGP	SGI	SPL (cm)	
Aluminum Foil	Mature green stage 46 (DAA)	41.45b	13.49b	65.34a	5,62a	2.76a
	Mature half red ripe 49 (DAA)	64.45b	12.23b	79.56a	7.95a	3.71a
	Mature full red ripe 52 (DAA)	72.67b	11.56b	97.54a	9.23a	4.98a
Cloth Bag	Mature green stage 46 (DAA)	53.51a	14.54a	51.12b	4.02b	2.01b
	Mature half red ripe 49 (DAA)	70.45a	13.74a	67.56b	4.89b	2.26b
	Mature full red ripe 52 (DAA)	76.67a	12.89a	71.90b	6.78b	3.06b

*Means with the same letter(s) within a column are not significantly different

KEY

SGP = seed germination percentage **SGI** = seed germination index **SPL** = seedling plumule length

SVI = seedling vigour index **EC** = seed leachate electro-conductivity **SMC** = seed moisture content

DAA = days after anthesis

The analysis of variance revealed significant influences of harvest stage on all seed quality parameters, including seed leachate electro-conductivity (SLE), seed moisture content (SMC), seed germination percentage (SGP), seed germination index (SGI), seedling plumule length (SPL), and seedling vigour index (SVI). Packaging material also significantly affected these parameters, with varying levels of significance. This is similar to the reports of Zanele *et al.* (2024) who reported that harvest stage and packaging has a combined effect on soybean seed quality. Furthermore, the interaction between harvest stage and packaging material was highly significant for all seed quality parameters which agrees to the findings of Msaakpa and Apuu (2020) where they reported highest germination attributes in tomato seeds harvested at ripened mature stage (80 days after anthesis) stored in aluminum foil bag compared to seeds from fruits harvested at green matured and

partially ripened matured stage (40 and 60 days after anthesis respectively). The results suggest that seeds harvested at the mature full red ripe stage (52 days after anthesis) exhibited the highest SLE, SGP, SGI, SPL, and SVI values. These findings imply that seeds obtained at this stage had reached full physiological maturity, which likely contributed to their superior performance in the measured quality parameters. This is in line with the report of Mandeep *et al.* (2020) where rice harvested at physiological maturity was observed to record high germination attributes. Seeds harvested at the mature green stage (46 days after anthesis) had the highest SMC after storage, suggesting that seeds at this stage may be more prone to moisture loss during storage. Suggesting that the seed coat of mature seeds is often more developed, providing better protection against water loss and gain. Immature seeds may have a less developed seed coat, making them more prone to moisture absorption. Seeds

packaged in aluminium foil consistently outperformed those packaged in cloth bags for most seed quality parameters, including SGP, SGI, SPL, and SVI. This suggests that aluminium foil packaging provides better protection for seeds, maintaining their quality and viability. Conversely, cloth bag packaging resulted in higher SLE and SMC values, indicating potential seed deterioration (Dadlani *et al.*, 2023).

Across maturity stages, the 48–52 DAA (half-red to full-red stage) consistently produced seeds with superior physiological quality under both packaging conditions, confirming that seed maturity at harvest is a primary determinant of viability and

vigour. However, the marked differences between packaging materials emphasizes the importance of the storage environment. Aluminium foil, being moisture-proof and non-permeable, provided a more stable microenvironment, leading to reduced seed deterioration and enhanced germination attributes.

CONCLUSION

The study concludes that harvesting fruits of “Shombo” at the full red ripe stage (52 DAA) yields seeds with the best quality characteristics. Additionally, storing seeds in aluminum foil proved more effective at preserving viability and vigor than cloth bags.

REFERENCES

- Abdul-Baki, A.A. and Anderson, J. D. (1973). Vigour Determination in Soybean Seed by Multiple Criteria. *Crop Science*, 13, 630
- Clement, C. R., De Cristo-Araújo, M., D'Eeckenbrugge, G. C., Pereira, A. A., and Picanço- Rodrigues, D. (2010). Origin and domestication of native Amazonian crops. *Diversity*, 2 (1) , 72–106.
- Clifford, U., Kingsley, A. and Queen, F. (2024). Evaluation of the Growth and Yield of Three Varieties of Pepper (*Capsicum* Spp) in Delta State, Nigeria. *Admiralty Journal of Multidisciplinary Research*, 1(2), 261-272
- Costa, C. J., Meneghello, G. E., Jorge, M. H. A., and Costa, E. (2021). The importance of physiological quality of seeds for agriculture. *Colloquium Agrariae*, 17(4), 102–119.
- Dadlani, M., Gupta, A., Sinha, S.N. and Kavali, R. (2023). Seed Storage and Packaging. In: Dadlani, M., Yadava, D.K. (eds) *Seed Science and Technology*. Springer, Singapore. https://doi.org/10.1007/978-981-19-5888-5_11
- Dobón-Suárez, A., Zapata, P. J., and García-Pastor, M. E. (2025). A Comprehensive Review on Characterization of Pepper Seeds: Unveiling Potential Value and Sustainable Agrifood Applications. *Food*, 14 (1 1) , 1 9 6 9 . <https://doi.org/10.3390/foods14111969>
- Esther, E. E., Christian, O. E., Olumuyiwa, O. and Ruth, O. I. (2021). Evaluation of cypermethrin insecticides on the growth of some selected soil bacteria isolated from Makurdi, Middle Belt, Nigeria. [African Journal of Microbiology Research](#), 15(2):75-81
- FAOSTAT. (2025). Production of pepper (*Piper* spp): top ten producers. <https://www.fao.org/faosta/#data/QCL>
- Guaguiyi, F.N., Nwonu, O. P and Umebali, E.E. (2025). Socioeconomic determinants of small scale fresh pepper marketing in Awka South Local Government Area, Anambra State, Nigeria. *Journal of Food and Fibre Production*, 4(1), 113-120
- Hartono, A., Barus, B. and Simanihuruk, D. (2022). Fertilizer recommendation for pepper based on soil properties and nutrient uptake. IOP Conference Series: *Earth and Environmental Science*. 974. 0 1 2 0 4 7 . 1 0 . 1 0 8 8 / 1 7 5 5 - 1315/974/1/012047
- International Seed Testing Association (ISTA). (2015). *International rules for seed testing* Basserdorf, Switzerland International Seed Testing Association.
- International Seed Testing Association (ISTA). (2018). *International Rules for Seed Testing: Chapter 9 — Determination of Seed Moisture Content*. Bassersdorf, Switzerland: ISTA.
- Kwon, D. Y., Soon-Hee, K., Chung, K. R., Daily, J. W., and Park, S. (2023). Science and philosophy of Korea traditional foods (K-food). *Journal of Ethnic Foods*, 10(1). 65-73
- Mandeep, K., Navjyot, K., Tarvinder, P.S. and Rajinder, S. (2020). Effect of Packaging Materials on Seed Quality Attributes of Basmati Rice during Seed Storage under Ambient Environmental Conditions. *Seed Res.* 48(1): 42-48
- Msaakpa, T.S. and Apuu, J. (2020). Effects of Harvesting Stages, Packaging Materials and Storage Duration on Seed Quality of Tomato (*Lycopersicon lycopersicon* Mill) Varieties. *Journal of Sustainable Agric. Environ.* 18 (1), 175-191
- Ndagana, M. K., Buba, A. and Umar, A. B. (2022). Effect of transplanting dates on growth and yield components of pepper (*capsicum* spp) in Badeggi, Nigeria. FUDMA *Journal of Agriculture and Agricultural Technology*, 7(2), 146-154
- RajKumar, S. T., Satish, D. and Sachchidanand, T. (2021). Influence of packaging materials and storage conditions on seed germination ability and biochemical changes in some medicinal plants of

- Indian forests. *Frontiers in Forest and Global Change*, 12(6), 56-73
- Ramos, K. M. O., Matos, J. M. M., Martins, R. C. C. and Martins, I. S. (2012). Electrical conductivity testing as applied to the assessment of freshly collected *Kielmeyera coriacea* Mart. Seeds. *I S R N A g r o n .* D O I : 10.5402/2012/378139.
- Shereen, S., Kuntal, B., Soham, M., Bigyananda, M., Kajal, M. C. and Puspendu. D. (2025). Influence of conditions and packaging materials on physiological quality parameters of wheat seeds during storage. *Journal of Stored Products Research*, 111. <https://doi.org/10.1016/j.jspr.2025.102566>
- Tetteh, R., Aboagye, L.M. and Darko, R. (2021). Influence of Different Maturity Stages on Tomato (*S o l a n u m lycopersicum* L.) Seed Quality during Storage at -20C. *Agricultura Science Digest*. 41(4), 624-627. DOI: 10.18805/ag.D-328
- Tripodi, P., Rabanus-Wallace, M.T., Barchi, L., Kale, S., Esposito, S., Acquadro, A., Schafleitner, R., van Zonneveld, M., Prohens, J., Diez, M.J., Börner, A., Salinier, J., Caromel, B., Bovy, A., Boyaci, F., Pasev, G. and Stein N. (2021). Global range expansion history of pepper (*Capsicum* spp.). *Proc Natl Acad Sci U S A*. 118(34). doi: 10.1073/pnas.2104315118.
- Zanele, M. A., Mariette, T, and Quenton, K. (2024). Effect of storage conditions on soybean seed quality produced by smallholder farmers within two districts of Gauteng, South Africa. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 125(1), 85–92
-