International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Survey of Farmer Practices for Sustainable Management of Fusarium wilt of *Cajanus cajan* L. Wilt in Munger

Gouri Singh[1], Dr. Vivek Kumar Singh[2]

[1]Research scholar, University Department of Botany,
T.M. Bhagalpur University, Bhagalpur
[2]Senior Assistant Professor, University Department of Botany
T.M. Bhagalpur University, Bhagalpur

Abstract

Pigeon pea (*Cajanus cajan* L.), a major pulse crop in Bihar, contributes significantly to household nutrition and income security. However, Fusarium wilt, caused by *Fusarium udum*, remains a critical constraint, reducing yields by 20–40% in endemic areas. This study, conducted in selected villages of Munger district, surveyed 90 farmers to assess the incidence of wilt Butler, prevailing management practices, and awareness about biological control. Data were collected through structured questionnaires and focus group discussions, and analyzed using percentage distribution, frequency tables, and chi-square tests. Findings indicate that although traditional practices like crop rotation and application of farmyard manure are widespread, adoption of resistant varieties and biological controls such as *Trichoderma* remains negligible. Constraints include high input costs, weak extension support, and limited access to quality seeds. The study emphasizes integrating farmer knowledge with modern eco-friendly practices to develop sustainable disease management strategies.

Keywords: Pigeon pea (*Cajanus cajan* L.), Fusarium wilt, farmer practices, Munger, biological control, sustainable agriculture

1. Introduction

Pigeon pea (*Cajanus cajan* L.) is one of the most important pulse crops cultivated in India, occupying a central place in the rural economy and diet of millions of households. It contributes not only to food and nutritional security but also to the sustainability of agricultural systems through its nitrogen-fixing capacity. In India, pigeon pea is grown over 4.5 million hectares with an annual production of 4.2 million tonnes (Directorate of Pulses Development, 2023). Bihar accounts for nearly 0.15 million hectares under pigeon pea cultivation, with Munger district emerging as a significant production pocket due to its favorable agro-climatic conditions, fertile alluvial soils, and long-standing tradition of pulse cultivation (Directorate of Economics and Statistics, 2023; Government of Bihar, 2025). The district has a substantial share of its total cultivated land devoted to pulses, particularly pigeon pea, with an estimated agricultural area of around 1.4–1.6 lakh hectares, largely characterized by rainfed farming systems (Ministry of Agriculture and Farmers Welfare, 2023). The crop serves as a vital source of protein for resource-poor households and provides supplementary cash income to smallholder farmers, thereby playing an important role in enhancing livelihood security and nutritional sustainability in the region (Indian Council of Agricultural Research, 2021; Kumar et al., 2020).

1.1 Importance of Pigeon Pea in Bihar's Agriculture

In Bihar, pigeon pea holds a unique position as both a subsistence and a commercial crop. It is widely grown under rainfed conditions, often in mixed or intercropping systems with cereals and oilseeds. According to the Ministry of Agriculture & Farmers Welfare (2023), pigeon pea contributes about 10–12% of the total pulse production in the state. Farmers prefer it for its drought tolerance, multiple uses (dal, fodder, fuelwood), and ability to thrive in marginal soils. However, despite its resilience, the crop faces severe challenges from biotic stresses, particularly wilt disease.

1.2 Fusarium Wilt: a major constraint

Among the various diseases of pigeon pea, Fusarium wilt, caused by *Fusarium udum* Butler, is the most destructive. The disease is soil-borne and persists for years, making its management particularly difficult. Wilt incidence can range between 15% and 70% depending on variety, soil type, and management practices (ICAR–IIPR, 2022). In Munger district, field-based evidence from Bihar and adjoining eastern Indo-Gangetic regions indicates that farmers frequently experience significant yield losses in pigeon pea due to Fusarium wilt, which has contributed to reduced productivity and, in some cases, a shift away from pulse cultivation (Indian Council of Agricultural Research, 2019; Indian Institute of Pulses Research, 2020). The disease is caused by *Fusarium udum*, a soil-borne pathogen that invades the root system and disrupts vascular tissues, leading to characteristic symptoms such as yellowing and drooping of leaves, vascular discoloration, wilting, and eventual plant death (Nene, Kannaiyan, & Reddy, 1996; Saxena et al., 2010). Beyond direct yield reduction, wilt infection also adversely affects grain quality and seed viability, thereby intensifying economic stress among small and marginal farmers who depend on pigeon pea as both a nutritional and cash crop (Sharma et al., 2016; Food and Agriculture Organization, 2019).

1.3 Current Management Practices and Gaps

Over the years, several management strategies have been recommended to control Fusarium wilt in pigeon pea, including crop rotation, intercropping, application of organic amendments, seed treatment with fungicides and bio-control agents (such as *Trichoderma* spp.), and the adoption of resistant varieties such as 'BDN-708' and 'MA-3' (Indian Institute of Pulses Research, 2019; Indian Council of Agricultural Research, 2020; Sharma et al., 2016). These integrated disease management practices are widely recommended under national pulse improvement programs to reduce soil-borne inoculum and enhance crop resilience under diverse agro-climatic conditions. However, adoption at the farmer level remains inconsistent. Field observations and previous extension reports suggest that cultural practices such as crop rotation and application of farmyard manure (FYM) are more common, whereas modern eco-friendly practices like the use of *Trichoderma viride* or *Pseudomonas fluorescens* are rarely adopted (Singh et al., 2021). Limited availability of resistant seeds, lack of awareness, and weak extension networks further exacerbate the problem.

1.4 Research Gap

Despite the seriousness of Fusarium wilt in Bihar, there has been limited systematic documentation of how farmers in Munger district actually manage the disease. Most available studies are experimental trials from research stations or general extension bulletins that do not capture the ground realities of farmer behavior (Hareesh et al., 2020; Indian Council of Agricultural Research publications). There is inadequate understanding of:

- How socio-economic factors influence adoption of management practices.
- The extent of farmer awareness about biological control options.
- The constraints farmers face in accessing resistant varieties or extension support.

This gap in knowledge makes it difficult to design localized, farmer-friendly strategies that integrate traditional practices with modern approaches.

1.5 Rationale of the Study

This study is designed to fill that gap by surveying pigeon pea farmers in Munger district to identify the incidence of wilt, document existing management practices, and assess awareness of biological control measures. Given the predominance of marginal and smallholders in the district, the findings are expected to provide insights into how socio-economic factors shape disease management. By combining farmer knowledge with scientific recommendations, the study also aims to propose integrated strategies for sustainable wilt management.

2. Materials and Methods

2.1 Study Area

The study was conducted in Munger district of Bihar, a region well-known for pigeon pea cultivation. Munger lies between 24°22′–25°30′ N latitude and 85°30′–87°30′ E longitude, with an average annual rainfall of 1100–1200 mm, mostly during the monsoon months (June–September) **(**India Meteorological Department, 2020; Government of Bihar, 2025**).** The district has a predominantly alluvial soil base with patches of loamy soil, well-suited for pulse cultivation. Pigeon pea is widely grown under rainfed conditions in the blocks of Khaira, Asarganj, Tarapur, and Dharhara, often in rotation with rice, wheat, or maize. The area was selected as it represents the diversity of pigeon pea farming systems and also records frequent incidence of Fusarium wilt.

2.2 Research Design

The research employed a survey design, combining structured questionnaires with focus group discussions (FGDs) to capture both quantitative and qualitative data. A stratified random sampling technique was adopted to ensure representation of different farmer categories based on landholding size (marginal, small, medium).

2.3 Sample Size and Sampling Procedure

A total of **90 farmers** were surveyed across four blocks. The distribution was:

- Khaira: 25 farmers
- Asarganj: 20 farmers
- Tarapur: 25 farmers
- Dharhara: 20 farmers

The sample size was determined considering time, resources, and the need for statistical analysis. Marginal farmers (<1 ha) constituted the majority (around 70%), followed by small (1–2 ha) and medium farmers (>2 ha).

2.4 Tools of Data Collection

2.4.1 Pre-tested Questionnaire:

- Contained structured and semi-structured questions.
- Sections included demographic profile, landholding, cropping pattern, wilt incidence, and management practices.
- Both close-ended and open-ended questions were included for triangulation of responses.

2.4.2 Focus Group Discussions (FGDs):

- Conducted in each block with 8–10 farmers.
- Used to validate questionnaire data and capture farmers' collective perceptions on disease management and constraints.

2.5 Parameters Recorded

The following parameters were systematically documented:

- **Cropping pattern and rotation practices**: whether farmers rotated pigeon pea with cereals, oilseeds, or pulses.
- **Use of organic manures and oilseed cakes**: including FYM, compost, and neem cake.
- **Seed treatment practices**: chemical fungicides (e.g., carbendazim, thiram) and biological agents (*Trichoderma viride* sp., *Pseudomonas fluorescens* sp.).
- **Chemical fungicide/pesticide application**: type, frequency, and cost.
- **Awareness about resistant varieties**: adoption of improved varieties like BDN-708, MA-3, or local landraces.
- **Access to extension services**: frequency of visits by extension officers, participation in training or KVK programs.

2.6 Data Analysis

Data were analyzed using a combination of descriptive and inferential statistics:

- **Percentage analysis**: to describe the proportion of farmers adopting different practices.
- **Frequency distribution tables**: to summarize adoption patterns.
- **Chi-square tests (χ^2 test of independence)**: The Chi-square (χ^2) test of independence was employed to examine the association between socio-economic variables (such as education level, landholding size, and access to credit) and the adoption of disease management practices among farmers. This non-parametric test is appropriate for categorical data and helps determine whether observed differences between variables are statistically significant. The test statistic was computed using the following formula:

  $$\chi^2 = \sum(O - E)^2/E$$

  where O = observed frequency, E = expected frequency.
  The expected frequencies were calculated based on the assumption of independence between variables.
- **Level of significance**: A **5% level of significance (α = 0.05)** was adopted to test the null hypothesis. If the calculated χ^2 value exceeded the critical value from the Chi-square distribution table at the given degrees of freedom, the null hypothesis of independence was rejected, indicating a statistically significant association between the variables.

This method is widely used in socio-economic and agricultural research to analyze relationships between categorical variables (Agresti, 2018; Zar, 2010).

2.7 Ethical Consideration

- Farmers were informed about the purpose of the study and their consent was obtained before interviews.
- Data were kept confidential and used strictly for research purposes.

2.8 Limitations

- The sample size was relatively small (90 farmers) due to logistical constraints.
- The study relied on farmer-reported data, which may involve recall bias regarding disease incidence.
- Results are specific to Munger district and may not be generalizable to all pigeon pea regions of Bihar.

3. Results

3.1 Socio-Economic Profile of Farmers

The surveyed farmers were predominantly marginal and smallholders. Out of the 90 respondents, 65 (72.2%) were marginal farmers with less than 1 hectare of land, 19 (21.1%) small farmers owning 1–2 hectares, and only 6 (6.7%) medium farmers with more than 2 hectares. Education levels were modest: 45% had completed only primary schooling, 32% had studied up to secondary level, while just 23% had higher secondary education or above.

Family size varied between 5–8 members in most households, indicating labor availability but also economic pressure. Only 30% of the farmers reported access to formal credit through banks or cooperatives, while the rest relied on informal sources such as moneylenders. This socio-economic background significantly influenced technology adoption and investment in disease management.

Table 1. Socio-Economic Profile of Respondents (n=90)

Socio-Economic Indicator	Category	Number	Percentage
Landholding Size	Marginal (<1 ha)	65	72.2%
	Small (1–2 ha)	19	21.1%
	Medium (>2 ha)	6	6.7%
Education Level	Primary	41	45.6%
	Secondary	29	32.2%
	Higher Secondary & above	20	22.2%
Access to Credit	Formal (banks/cooperatives)	27	30.0%
	Informal (moneylenders)	63	70.0%

3.2 Incidence of Fusarium Wilt

Farmers were asked to report wilt occurrence in their fields over the past two cropping seasons. The results revealed that 56 out of 90 farmers (62.2%) had experienced moderate to severe wilt in their pigeon pea plots. Wilt was more prevalent in villages practicing continuous pigeon pea cultivation without rotation. In contrast, areas where pigeon pea was rotated with cereals (rice, wheat) reported relatively lower incidence.

Table 2. Incidence of Fusarium Wilt (Block-wise Analysis) (n=90)

Block	No. of Farmers Reporting Wilt	Percentage
Tarapur	17	68%
Khaira	16	65%
Asarganj	12	60%
Dharhara	11	55%
Overall	56	62.20%

Block-wise analysis indicated slightly higher wilt prevalence in Tarapur (68%) and Khaira (65%) compared to Dharhara (55%) and Asarganj (60%). Farmers also observed that wilt incidence increased in fields with poor drainage and low organic matter.

3.3 Existing Farmer Practices

Survey findings showed that farmers adopted a mix of traditional and modern practices to manage wilt. Crop rotation (70%) and application of farmyard manure/neem cake (55%) were the most common practices. However, the use of resistant varieties was limited (20%), and only 15% of farmers practiced seed treatment.

Chemical fungicides were used by 30% of farmers, but adoption was inconsistent due to high costs. Awareness and use of biological control (*Trichoderma* sp., *Pseudomonas* sp.) were very low - only 9% reported awareness, and just 5% had ever tried them.

Table 3. Management Practices Adopted by Farmers (n=90)

Practice	Farmers Using	Percentage
Crop rotation with cereals	63	70.0%
Application of FYM/neem cake	50	55.6%
Resistant varieties	18	20.0%
Chemical fungicide application	27	30.0%
Seed treatment (chemical/biological)	14	15.6%
Awareness of *Trichoderma/Pseudomonas*	8	8.9%

3.4 Awareness and Adoption of Biological Control

FGD findings revealed that while some farmers had heard of bio-agents during KVK (Krishi Vigyan Kendra) training, very few had access to such products in local markets. Only 8 farmers reported awareness, and of them, 4 had actually tried *Trichoderma* seed treatment. The main constraints cited were unavailability, lack of demonstrations, and doubts about efficacy.

Table 4. Awareness and Adoption of Biological Control

Category	Number	Percentage
Farmers aware of bio-agents	8	8.9%
Farmers not aware	82	91.1%
Farmers who tried bio-agents	4	4.4%
Farmers who did not try	86	95.6%

This indicates a critical extension gap, as biological control is eco-friendly and cost-effective compared to repeated fungicide sprays.

3.5 Constraints Reported by Farmers

Farmers identified several constraints in managing Fusarium wilt effectively:

3.5.1 Limited availability of resistant varieties (68%)

Improved seeds were either unavailable or expensive.

3.5.2 High cost of fungicides (52%)

Marginal farmers avoided chemical sprays due to financial burden.

3.5.3 Poor extension services (61%)

Infrequent visits from agriculture officers and lack of field demonstrations.

3.5.4 Unawareness of biological methods (72%)

Bio-agents were absent from local markets.

3.5.5 Credit constraints (70%)

High dependence on moneylenders reduced capacity to invest in inputs.

3.6 Association Between Socio-Economic Factors and Practices

3.6.1 Education and Adoption of Resistant Varieties

Table 5: Chi-Square Analysis of Education Level and Adoption of Resistant Varieties among Farmers

Cell	O	E	χ^2
Primary + Adopted	4	8.2	2.15
Primary + Not Adopted	37	32.8	0.54
Secondary + Adopted	6	5.8	0.007
Secondary + Not Adopted	23	23.2	0.002
Higher Secondary + Adopted	8	4.0	4.00
Higher Secondary + Not Adopted	12	16.0	1.00
Total χ^2 Value			**7.699**

A chi-square test was conducted to examine whether education level influenced adoption of resistant varieties. Results showed a significant association ($\chi^2 = 7.699$, $p < 0.05$). Farmers with higher secondary education or above were more likely to adopt improved varieties compared to those with only primary schooling.

3.6.2 Landholding Size and Fungicide Use

Table 6: Chi-Square Analysis of Landholding Size and Fungicide Use among Farmers

Cell	O	E	χ^2
Marginal + Use	14	19.5	1.55
Marginal + No Use	51	45.5	0.66

Small + Use	8	5.7	0.93
Small + No Use	11	13.3	0.40
Medium + Use	5	1.8	5.69
Medium + No Use	1	4.2	2.44
Total χ^2 Value			**11.670**

Analysis revealed a significant relationship ($\chi^2 = 11.670$, $p < 0.05$) between landholding size and fungicide use. Medium farmers were more likely to use fungicides regularly, whereas marginal farmers largely avoided them due to cost.

3.6.3 Credit Access and Biological Control Adoption

Table 7: Chi-Square Analysis of Credit Access and Adoption of Biological Control Practices among Farmers

Cell	O	E	χ^2
Formal + Tried Bio-agents	3	1.2	2.70
Formal + Did Not Try	24	25.8	0.13
Informal + Tried Bio-agents	1	2.8	1.16
Informal + Did Not Try	62	60.2	0.05
Total χ^2 Value			**4.040**

Farmers with access to formal credit were more likely to experiment with bio-agents than those dependent on informal credit. However, due to low sample size, the association was weak ($\chi^2 = 4.040$, not significant at $p < 0.05$).

Table 8: Chi-Square Association Results

Variable Pair	χ^2 Value	Significance	Result
Education × Adoption of resistant varieties	7.699	$p < 0.05$	Significant
Landholding × Fungicide use	11.670	$p < 0.05$	Significant
Credit access × Bio-control adoption	4.040	$p > 0.05$	Not Significant

4. Discussion

4.1 Fusarium Wilt Incidence in Context

The survey results confirm that Fusarium wilt is a persistent and severe constraint in pigeon pea cultivation in Munger, with more than 60% of farmers reporting moderate to high incidence. This aligns with earlier reports from the Indian Institute of Pulses Research (ICAR–IIPR, 2022), which identified Bihar as one of the endemic regions for *Fusarium udum*, based on long-term surveillance, disease mapping, and multi-location trials conducted under the All India Coordinated Research Project on Pigeonpea (Sharma et al., 2016; Saxena et al., 2010; Indian Council of Agricultural Research, 2019). Similar studies in Eastern Uttar Pradesh and Jharkhand have also reported wilt incidence ranging from 50–70% (Singh et al., 2021). The high prevalence is linked to monocropping systems, poor soil health, and lack of resistant varieties in farmers' fields.

4.2 Traditional Practices and Their Effectiveness

Cultural practices such as crop rotation (70%) and application of organic manures (55%) remain the backbone of wilt management. These findings resonate with earlier research showing that rotation with cereals reduces pathogen inoculum and enhances soil health (Chaudhary et al., 2019). Application of FYM and neem cake also helps improve soil microbial balance, indirectly suppressing wilt. While these practices are cost-effective and accessible to resource-poor farmers, they are insufficient to provide reliable control when used in isolation.

4.3 Adoption of Improved Varieties and Modern Inputs

Despite the availability of wilt-resistant pigeon pea varieties such as ‘BDN-708’, ‘MA-3’, and ‘ICPL-87119’ (popularly known as Asha), adoption in Munger remains low (20%). The key reasons are seed unavailability, higher cost, and lack of awareness. This is consistent with findings from Maharashtra and Madhya Pradesh, where adoption of resistant varieties was below 30% among smallholders (Kumar et al., 2022). The survey also revealed that chemical fungicides were used by only 30% of farmers, primarily those with larger landholdings. This reflects the dual constraint of affordability and risk perception: marginal farmers perceive chemical inputs as expensive with uncertain returns.

4.4 Awareness and Adoption of Biological Control

Perhaps the most critical finding is the extremely low awareness and adoption of biological control agents. Only 9% of farmers had heard of *Trichoderma* or *Pseudomonas*, and just 5% had ever used them. Yet, numerous experimental studies demonstrate that these bio-agents are effective in reducing wilt incidence by 30–50% under field conditions (Sharma et al., 2018; ICAR–IIPR, 2023). The gap between research recommendations and farmer practice highlights systemic weaknesses in extension delivery. KVKs and state agriculture departments have not adequately demonstrated the utility of biological methods at the field level. Without regular training, supply chains, and subsidy support, adoption is unlikely to increase.

4.5 Socio-Economic Determinants of Adoption

The chi-square analysis underscores the role of socio-economic factors in shaping management practices. Education level was significantly associated with adoption of resistant varieties, confirming earlier studies that education improves capacity to understand and accept new technologies (Reddy & Mishra, 2017). Similarly, landholding size was associated with fungicide use, suggesting that larger farmers are more willing to invest in chemical inputs. Interestingly, access to credit did not significantly influence biological control adoption, largely because bio-agents were unavailable locally, regardless of financial capacity. This finding implies that even well-resourced farmers cannot adopt technologies that are absent from the market ecosystem.

4.6 Comparison with Other Regions

In Andhra Pradesh and Telangana, where systematic extension and seed distribution programs were implemented, resistant variety adoption reached up to 45% (Rathore et al., 2020). Similarly, in Karnataka, farmer field schools promoting *Trichoderma* saw adoption rise to 25% within three years (Deshmukh et al., 2019). By contrast, in Munger, weak institutional support has left farmers largely dependent on indigenous practices. This suggests that the gap is not technological but institutional and infrastructural.

4.7 Policy and Extension Implications

The findings carry strong policy relevance for Bihar's pulse sector. India continues to depend on imports for pulses, with an annual import bill exceeding USD 1.5 billion (FAO, 2021). Enhancing pigeon pea productivity in Bihar through wilt management could reduce this dependence. The government's National Food Security Mission (NFSM-Pulses) already supports distribution of resistant seeds and demonstrations, but coverage in districts like Munger remains patchy. Strengthening Krishi Vigyan Kendras, farmer cooperatives, and input supply chains is crucial.

Moreover, promoting biological control aligns with India's sustainability goals under the National Mission on Sustainable Agriculture (NMSA). Unlike chemicals, bio-agents are environmentally safe, affordable, and can be produced locally by farmer producer organizations (FPOs). Integrating them with traditional practices could create a holistic integrated disease management (IDM) framework that is both farmer-friendly and ecologically sound.

4.8 Limitations of the Study

It is important to acknowledge that the study relied on self-reported data, which may have recall bias regarding disease incidence. The relatively small sample size (90 farmers) also limits the generalizability of findings. Nonetheless, the study provides valuable insights into ground-level realities in Munger, which can guide future interventions and larger-scale studies.

5. Conclusion and Recommendations

The survey highlights that Fusarium wilt remains a major threat to pigeon pea production in Munger, with more than 60% of farmers experiencing crop losses. Despite the seriousness of the problem, management is still dominated by traditional practices such as crop rotation and the use of farmyard manure. While these methods provide partial relief, they are inadequate to control the disease effectively. Adoption of resistant varieties is very low (20%), and awareness of biological control agents such as *Trichoderma* and *Pseudomonas* is almost negligible. Chemical fungicides are used by a minority of relatively better-off farmers but remain financially out of reach for most marginal households.

The study further establishes that socio-economic factors significantly influence adoption patterns. Farmers with higher education levels are more likely to adopt resistant varieties, while those with larger landholdings tend to use chemical fungicides. However, the lack of market availability and weak extension systems restrict wider use of bio-control measures, regardless of farmers' willingness or resources. These findings mirror the broader challenge of bridging the gap between laboratory innovations and farmer fields.

Recommendations

Based on the findings, a comprehensive strategy is essential for the sustainable management of Fusarium wilt in Munger district. This includes strengthening seed systems by ensuring timely availability of resistant pigeon pea varieties through state seed corporations, cooperatives, and farmer producer organizations; promoting biological control through subsidized distribution and local production of bio-agents such as *Trichoderma* and *Pseudomonas*; and enhancing capacity building via regular farmer training, field demonstrations, and farmer field schools conducted by Krishi Vigyan Kendra (KVKs). Additionally, an integrated disease management (IDM) approach should be encouraged, combining crop rotation, farmyard manure (FYM), resistant varieties, seed treatment, and bio-control measures to reduce reliance on chemical fungicides. Policy support is also crucial by incorporating wilt management into Bihar's extension and subsidy frameworks under National Food Security Mission–Pulses and the National Mission on Sustainable Agriculture, along with improving access to institutional credit for smallholders to minimize dependence on informal sources. Overall, addressing wilt effectively requires a multi-dimensional approach that integrates indigenous farmer knowledge with modern eco-friendly practices; with strong extension support and policy backing, pigeon pea cultivation in Munger can become more resilient, enhancing farmer incomes, nutritional security, and pulse self-sufficiency in Bihar.

Acknowledgement

The authors sincerely acknowledge the support of the University Department of Botany, T.M. Bhagalpur University, Bhagalpur, and express gratitude to participating farmers of Munger district for their valuable cooperation and field-level insights during the study.

References

1. Agresti, A. (2018). Statistical methods for the social sciences (5th ed.). Pearson.
2. Chaudhary, R., Singh, A., & Yadav, S. (2019). Crop rotation and soil amendments in managing soil-borne diseases of pulses. Journal of Plant Disease Science, 14(2), 120–127. http://www.jplantdis.org
3. Deshmukh, R., Patil, S., & Kulkarni, A. (2019). Farmer field schools and adoption of bio-control in pigeon pea wilt management. Indian Journal of Extension Education, 55(3), 67–74. https://epubs.icar.org.in/index.php/IJEE/article/view/105666
4. Directorate of Economics and Statistics. (2023). Agricultural statistics at a glance 2023. Ministry of Agriculture and Farmers Welfare, Government of India. https://agricoop.nic.in
5. Directorate of Pulses Development. (2023). Annual report on pulse production in India. Ministry of Agriculture & Farmers Welfare, Government of India. https://dpd.gov.in/
6. FAO (2021). Pulses and food security: Global and regional trends. Rome: Food and Agriculture Organization of the United Nations.
7. FAO (2021). Pulses contribute to food security (FAO knowledge brief). Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/bitstream/handle/20.500.12608/7758/FAO-Pulses-Contribute-to-Food-Security.pdf?sequence=1&isAllowed=y
8. FAO (2021). World food and agriculture — Statistical yearbook 2021. Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/522c9fe3-0fe2-47ea-8aac-f85bb6507776/content
9. Food and Agriculture Organization. (2019). Pulses and their importance for food security and nutrition. FAO, Rome. https://www.fao.org
10. Government of Bihar. (2025). District statistical handbook: Munger. Directorate of Economics and Statistics, Patna. https://state.bihar.gov.in
11. Government of India, Ministry of Agriculture & Farmers Welfare. (2025). Agricultural Statistics at a Glance 2024–25. https://agricoop.nic.in/

12. Hareesh, M., Lal, H. C., Ekka, S., Kumar, N., Kumar, B., Deepti, S. & Barnwal, M. K. (2020). Management of pigeonpea wilt using host resistance, chemicals, soil amendments and bioagents. Journal of Food Legumes, 33(4), 245-251. https://doi.org/10.59797/jfl.v33i4.568
13. ICAR–IIPR. (2022). Crop protection compendium for pigeon pea. Kanpur: Indian Institute of Pulses Research.https://iipr.icar.gov.in/
14. ICAR–IIPR. (2023). Improved pigeon pea varieties and their cultivation practices. Extension Bulletin. https://iipr.icar.gov.in/extension-bulletins
15. India Meteorological Department. (2020). Climatological tables of observatories in India (1981–2010). Ministry of Earth Sciences, Government of India. https://mausam.imd.gov.in
16. Indian Council of Agricultural Research. (2019). Annual report 2018–19. ICAR, New Delhi. https://icar.org.in
17. Indian Council of Agricultural Research. (2020). Improved technologies for pulse production. ICAR, New Delhi. https://icar.org.in
18. Indian Council of Agricultural Research. (2021). Vision 2050: Pulses. ICAR, New Delhi. https://icar.org.in
19. Indian Institute of Pulses Research. (2019). Package of practices for pulses. ICAR-IIPR, Kanpur. https://iipr.icar.gov.in
20. Indian Institute of Pulses Research. (2020). Vision 2050: Pulses research and development. IIPR, Kanpur. https://iipr.icar.gov.in
21. Kumar, P., Singh, R., & Sharma, V. (2022). Constraints in adoption of wilt-resistant pigeon pea varieties in central India. Legume Research, 45(5), 621–627. https://doi.org/10.18805/LR-6427
22. Kumar, S., Singh, R., & Singh, N. P. (2020). Pulses production in India: Trends and prospects. Indian Journal of Agricultural Sciences, 90(5), 874–883. https://doi.org/10.56093/ijas.v90i5.102345
23. Ministry of Agriculture and Farmers Welfare. (2023). Area, production and yield of principal crops. Government of India. https://agricoop.nic.in
24. Nene, Y. L., Kannaiyan, J., & Reddy, M. V. (1996). Pigeonpea diseases. Patancheru: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). https://www.icrisat.org
25. Rathore, A., Reddy, B. V. S., & Mishra, A. (2020). Adoption of improved pigeon pea technologies in Andhra Pradesh. Indian Journal of Agricultural Economics, 75(3), 445–460. https://www.isaeindia.org/
26. Reddy, V., & Mishra, P. (2017). Education as a determinant of technology adoption in Indian agriculture. Agricultural Economics Research Review, 30(2), 245–252. https://doi.org/10.5958/0974-0279.2017.00024.0
27. Saxena, K. B., Kumar, R. V., & Rao, P. V. (2010). Pigeonpea nutrition and its improvement. Journal of Food Legumes, 23(2), 81–88.
28. Sharma, M., Ghosh, R., Pande, S., & Rathore, A. (2016). Integrated disease management of Fusarium wilt of pigeonpea. Frontiers in Plant Science, 7, 253. https://doi.org/10.3389/fpls.2016.00253
29. Sharma, M., Ghosh, R., Telangre, R., & Rathore, A. (2016). Environmental influences on pigeonpea-Fusarium wilt interactions and stability of resistance. Frontiers in Plant Science, 7, 253. https://doi.org/10.3389/fpls.2016.00253

30. Sharma, M., Saxena, R. K., & Ghosh, R. (2018). Biological control of Fusarium wilt in pigeon pea under field conditions. Biocontrol Science and Technology, 28(1), 52–64. https://doi.org/10.1080/09583157.2017.1391178
31. Singh, A. K., Singh, U. P., & Singh, R. (2021). Incidence and management of Fusarium wilt of pigeonpea in eastern Uttar Pradesh. Journal of Food Legumes, 34(2), 120–125.
32. Singh, R., Prasad, A., & Kumar, P. (2021). Farmer adoption of wilt management practices in Eastern Uttar Pradesh. Indian Journal of Extension Education, 57(4), 122–127. https://epubs.icar.org.in/index.php/IJEE/article/view/114321
33. Zar, J. H. (2010). Biostatistical analysis (5th ed.). Pearson Education.

*****