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Integrated Agronomic, Nutritional, and Industrial Evaluation of Wheat Varieties Sonalika and K 9107 for Climate-Resilient Production and Food Security Enhancement in Assam

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Abstract

Wheat production in Assam remains limited compared to other Indian states due to high rainfall, soil acidity, terminal heat stress, and limited mechanization. This study presents a comprehensive, multidisciplinary evaluation of wheat varieties *Sonalika* and *K 9107* under Assam's agro-climatic conditions. The research integrates agronomic optimization, stress adaptability assessment, pest and disease resistance screening, grain quality characterization, nutraceutical profiling, industrial suitability analysis, and economic evaluation. Results demonstrate that optimized management (120:60:40 NPK kg ha^{-1} with split nitrogen, liming, and improved sowing techniques) enhanced yield by 22–26% over farmer practice. Liming improved soil pH from 5.1 to 6.0, increasing phosphorus availability by 48%. HD 2967 equivalent performance was observed in K 9107 for bread-making quality due to stronger gluten strength, while Sonalika showed suitability for biscuit manufacturing. Integrated nutrient management increased soil organic carbon by 0.15–0.18% over two seasons. The study provides actionable recommendations for sustainable wheat intensification and value-chain development in Assam.

Keywords: Climate-resilient wheat, Sonalika, K 9107, Agro-climatic adaptability, Grain quality and gluten strength, Sustainable nutrient management, Food security in Northeast India

Introduction

Wheat (*Triticum aestivum* L.) is the second most important cereal crop in India and a cornerstone of national food security. While traditionally concentrated in the Indo-Gangetic Plains, wheat cultivation has gradually expanded into non-traditional regions, including the Northeastern states such as Assam. However, wheat production in Assam faces multiple agro-climatic constraints—short winter duration, high residual soil moisture variability, acidic soils, erratic rainfall patterns, and increasing terminal heat stress associated with climate change. These factors significantly influence crop phenology, grain filling duration, yield stability, and grain quality.

Climate change projections for Northeast India indicate rising minimum and maximum temperatures, altered precipitation regimes, and increased frequency of extreme weather events. Terminal heat stress during the reproductive phase is particularly detrimental, causing chlorophyll degradation, reduced photosynthetic efficiency, membrane instability, accelerated senescence, and decline in grain weight. Therefore, climate-resilient varietal selection combined with adaptive agronomic management is essential to ensure sustainable wheat production in Assam.

Two wheat varieties—**Sonalika** and **K 9107**—hold particular relevance for Eastern and Northeastern India. **Sonalika** is an early-maturing, widely adaptable variety known for its heat escape mechanism and stable performance under short winter conditions. **K 9107** (Deva), developed for Eastern India, is characterized by medium maturity, good grain quality, and adaptability to late sowing conditions. However, comprehensive integrated evaluation of these varieties under Assam's specific agro-climatic gradients—covering agronomic performance, nutritional quality, and industrial suitability—remains limited.

Rationale ***:*** Most varietal evaluation studies in wheat focus predominantly on yield performance under stress conditions, often neglecting nutritional and industrial quality parameters. In the context of climate resilience and food security, productivity alone is insufficient. A holistic approach must integrate: a) **Agronomic performance** – yield stability, phenological adaptability, stress tolerance, b) **Nutritional evaluation** – protein content, micronutrient density, gluten strength, carbohydrate composition, c) **Industrial suitability** – milling recovery, flour quality, dough rheology, baking and processing performance.

Assam's growing population and increasing dependence on imported wheat from other states underline the need for regional self-sufficiency. Locally adapted, climate-resilient varieties can reduce transportation costs, ensure timely availability, and strengthen local food systems. Furthermore, improving nutritional quality aligns with national goals of addressing protein-energy malnutrition and micronutrient deficiencies.

An integrated evaluation of Sonalika and K 9107 will help determine: a) Their relative adaptability to Assam's valley agro-ecosystems, b) The extent of physiological resilience under terminal heat stress, c) Nutritional and industrial advantages for regional food processing sectors, d) Suitability for incorporation into climate-smart agricultural models.

Such a multidimensional assessment bridges the gap between field performance and food system application, contributing to both farmer income enhancement and consumer nutritional security.

Objectives of the Study

The present investigation is designed to achieve the following comprehensive objectives:

1. **To evaluate the agronomic performance and climate resilience of Sonalika and K 9107 under Assam agro-climatic conditions**, including assessment of phenology, yield attributes, stress tolerance indices, and stability across normal and delayed sowing environments.
2. **To analyze the physiological and biochemical responses of both varieties under heat stress**, focusing on chlorophyll retention, canopy temperature depression, membrane stability, antioxidant enzyme activity, and grain filling duration.
3. **To assess nutritional quality parameters**, including protein content, wet gluten percentage, carbohydrate profile, and micronutrient composition relevant to dietary security.

4. **To evaluate industrial processing quality**, including flour extraction rate, dough rheology characteristics, baking suitability, and value-addition potential for regional agro-industries.
5. **To develop an integrated climate-resilient production and utilization model** for sustainable wheat cultivation in Assam that links varietal performance with food security enhancement.

Significance of the Study

This research integrates agronomic science, plant physiology, nutritional analysis, and industrial quality assessment into a unified framework. By combining production and utilization perspectives, the study moves beyond conventional yield-focused evaluation and contributes to a comprehensive climate-resilient strategy. The findings are expected to: a) Provide scientific recommendations for varietal selection in Assam, b) Support state-level agricultural planning and extension services, c) Enhance farmer profitability through quality-based market linkage, d) Strengthen regional food security and nutritional sustainability, e) Contribute to climate-smart cereal production strategies in Northeast India.

Literature Review

Global Importance of Wheat under Climate Change

1.Food and Agriculture Organization (FAO). 2021. *FAOSTAT Statistical Database*. FAO, Rome, Italy. Government of India (2023). Agricultural Statistics at a Glance., Food and Agriculture Organization reports that wheat contributes nearly 20% of global caloric intake and is central to food security systems in both temperate and subtropical regions. However, climate variability—including terminal heat stress, erratic rainfall, and soil degradation—poses increasing threats to yield stability. We recently find in studies -Field Crops Research and Environmental and Experimental Botany demonstrate that integrated agronomic interventions significantly buffer climate-induced yield variability.

Critical Discussion: While much literature addresses wheat in semi-arid and Indo-Gangetic Plains ecosystems, limited peer-reviewed evidence exists for high-rainfall acidic zones like Assam. This creates a research gap addressed by the present study.

Soil Acidity and Liming in Wheat Systems

2. Gupta, R.K., and Yadav, O.P. 2017. Soil acidity and nutrient management for sustainable wheat production in Northeast India. *Indian Journal of Fertilisers*, 13(4): 44–52., 3. Fageria, N.K., & Baligar, V.C. (2008). Ameliorating soil acidity of tropical Oxisols by liming. Acidic soils ($pH < 5.5$) dominate Northeast India, resulting in: Aluminum toxicity, Phosphorus fixation, Reduced root proliferation.

Fageria and Baligar (2008) reported that liming tropical soils improves P availability by 30–50% and enhances root growth.

Research in Plant and Soil confirms: Liming reduces exchangeable Al^{3+}, Enhances microbial biomass carbon, Improves nitrogen mineralization

Synthesis with Present Study: Your findings (pH increase 5.1 → 6.0; 48% rise in P availability; 0.4–0.5 t ha^{-1} yield gain) align strongly with global liming literature but provide region-specific validation for Assam's alluvial acidic soils—an underreported ecosystem.

Nitrogen Management and Yield Optimization

Singh, G.P., and Sharma, P. 2019. Nitrogen management strategies for improving wheat productivity and grain protein content under eastern Indian conditions. *Journal of Cereal Research*, 11(2): 125–132.

Nitrogen is the most limiting nutrient in wheat production - Field Crops Research, European **Journal of Agronomy** demonstrate that split nitrogen application - Improves nitrogen recovery efficiency, Enhances tiller survival, Increases grain protein concentration. In study I got NUE increase from 28 → 38 kg grain/kg N, 15% rise in effective tillers, 0.8% protein enhancement.

Critical Interpretation: The synchronization of nitrogen with CRI and boot stages aligns with physiological nitrogen demand curves described in plant physiology literature. This confirms that temporal nutrient precision is more impactful than mere dose escalation.

Raised Bed Planting in High-Rainfall Agro-Ecosystems

Tandon, H.L.S. 2013. *Methods of Analysis of Soils, Plants, Waters and Fertilizers*. Fertiliser Development and Consultation Organisation (FDCO), New Delhi., Brady, N.C., and Weil, R.R. 2016. *The Nature and Properties of Soils* (15th ed.). Pearson Education, New Delhi.

Raised-bed planting has been widely evaluated in semi-arid regions; however, fewer studies focus on humid subtropical zones. **Research in Agricultural Water Management** shows - 12–20% water-use efficiency improvement, Enhanced root aeration, Reduced lodging and I got 12–17% yield improvement, 3.7 cm increase in root length, 15% water-use efficiency gain.

Literature Gap Filled: Most raised-bed literature emphasizes water scarcity; your work extends its relevance to high-moisture stress mitigation—an important conceptual contribution.

Thermal Regime and Terminal Heat Escape

Temperature during grain filling critically determines 1000-grain weight. When do I studies in Plant Physiology and Journal of Experimental Botany highlight - Each 1°C rise above optimum reduces grain weight by 3–5%., Heat stress accelerates senescence via reactive oxygen species (ROS). And in our observation get K 9107 maintained 44 g grain weight under mild heat stress, Sonalika escaped terminal heat due to early maturity.

Interpretation: This confirms genotype-specific adaptation strategies in Heat tolerance (physiological stability) and Heat escape (phenological adjustment), such differentiation is critical for climate-resilient varietal selection.

Disease Resistance under Humid Conditions

Humid environments increase rust and mildew incidence and as per Research in Crop Protection Reports we get Leaf rust causes 10–40% yield losses in susceptible cultivars. And our results became K 9107 lower rust incidence (5.2% vs 9.5%), Yield stability index > 1.05.

Comparative Insight: Disease resistance contributes indirectly to yield stability, especially in high-humidity regions where pathogen pressure is continuous.

Grain Quality and Gluten Functionality

Shewry, P.R., and Hey, S.J. 2015. The contribution of wheat to human diet and health. *Food and Energy Security*, 4(3): 178–202. Grain protein composition (glutenin/gliadin ratio) determines industrial utility. **Seminal work in Food and Energy Security demonstrates** - Gluten strength correlates positively with loaf volume. Our findings are Gluten Index: 84 (K 9107) vs 70 (Sonalika), Loaf volume: 545 cc vs 495 cc.

Industrial Relevance Discussion: Strong gluten network improves gas retention and dough stability. Moderate gluten enhances biscuit spread ratio. Thus, varietal diversification supports agro-processing value chains.

Nutraceutical Properties and Functional Foods

ICAR–Indian Institute of Wheat and Barley Research (IIWBR). 2022. *Annual Progress Report of the All India Coordinated Research Project on Wheat and Barley (AICRP-W&B)*. Karnal, Haryana., **Directorate of Economics and Statistics.** 2022. *Agricultural Statistics at a Glance*. Ministry of Agriculture & Farmers Welfare, Government of India.

Whole wheat phenolics contribute to antioxidant activity. Research in Journal of Cereal Science and Plant Foods for Human Nutrition confirms - Polyphenols (200–300 mg GAE/100 g) improve cardiovascular health markers and my reports are 210–260 mg GAE/100 g, 39% DPPH inhibition (K 9107)

Interpretation: These values place both varieties within functional food grade standards, supporting food security with nutritional quality.

Economic Sustainability and Adoption Feasibility

Government of Assam. 2022. *Statistical Handbook of Assam*. Directorate of Economics and Statistics, Guwahati. Agronomic innovation adoption depends on profitability. Studies in Agricultural Systems show B:C ratio >2.0 significantly increases farmer adoption probability and in results B:C improved from 1.64 → 2.31, Net income gain ₹21,500 ha^{-1}.

Policy Implication: Liming subsidy + quality-based procurement can close productivity gaps sustainably.

Materials and Methods

Agro-Ecological Characterization of Experimental Sites in Assam

The field experiments were conducted in representative wheat-growing districts of Assam situated within the Upper and Central Brahmaputra Valley agro-climatic zones. The region is characterized by humid subtropical conditions with acidic alluvial soils and high monsoonal rainfall. Each environmental parameter critically influences wheat growth, nutrient dynamics, and stress response.

Soil pH (4.9–5.6): Acidic Soil Constraints - The experimental sites exhibited strongly to moderately acidic soils (mean pH 5.2 ± 0.3). Such acidity is typical of Northeast India due to – a) High rainfallinduced leaching of basic cations (Ca^{2+}, Mg^{2+}, K^{+}), b) Dominance of Ulti sols and Incept sols , c) Aluminum (Al^{3+}) and iron (Fe^{3+}) toxicity under low pH.

Implications for Wheat – a) Phosphorus fixation increases at pH <5.5, reducing P availability by 30–50%., b) Exchangeable Al^{3+} toxicity impairs root elongation by 20–40%., c) Reduced microbial activity affects nitrogen mineralization.

Table no. 1

Parameter	Mean Value
pH (1:2.5 soil: water)	5.2
Exchangeable Al (cmol kg^{-1})	0.65
Available P (kg ha^{-1})	14.8

Liming @ 2 t ha^{-1} increased soil pH to 6.0, reduced exchangeable Al by 58%, and improved P availability to 21–23 kg ha^{-1}, resulting in yield enhancement of ~0.4–0.5 t ha^{-1}. Thus, soil acidity correction was a critical intervention for maximizing varietal performance.

Organic Carbon (0.75–1.2%): Soil Fertility Status

The soils showed moderate organic carbon content (mean 0.94%), reflecting – a) High biomass turnover due to warm climate, b) Rapid decomposition under humid conditions, c) Limited incorporation of crop residues

Significance in Wheat Production – a) Each 0.1% increase in soil organic carbon enhances available nitrogen by ~20–25 kg ha^{-1}., b) Improved soil structure enhances water retention capacity by 5–8%., c) Enhances microbial biomass carbon, supporting nutrient cycling. Integrated nutrient management (INM) increased soil organic carbon by 0.15–0.18% over two cropping cycles, contributing to – a) 8–12% higher nitrogen use efficiency (NUE), b) Improved root proliferation and tiller density. This parameter is particularly important in sustaining long-term productivity under intensive systems.

Annual Rainfall (1600–2200 mm): High Moisture Regime

The region receives 80–85% of rainfall during June–September (monsoon), while wheat is grown during the rabi season (November–March)., **Climatic Distribution Pattern:**

Table No.2

Season	Rainfall Contribution
Monsoon	78–85%
Post-monsoon	8–12%
Winter	5–10%

Although wheat is cultivated during relatively dry months, residual soil moisture and occasional winter showers influence – a) Germination and early establishment, b) Risk of waterlogging in low-lying fields, c) Nitrogen leaching losses.

Raised-bed sowing reduced temporary waterlogging and improved aeration, leading to – a) 12–17% increase in root biomass, b) 0.3–0.4 t ha^{-1} yield advantage over flat sowing, high rainfall also accelerates soil acidification, reinforcing the importance of liming.

Winter Temperature (10–24°C): Thermal Regime

The wheat-growing season is characterized by- a) Minimum temperature: 8–12°C (December–January), b) Maximum temperature: 22–26°C (February–March), c) Occasional terminal heat (>28°C) in late March. **Thermal Relevance for Wheat Physiology – a)** Optimal germination: 20–25°C, b) Tillering: 16–20°C, c) Grain filling: 18–24°C. Temperature data during the study:

Table No. 3

Growth Stage	**Mean Temperature (°C)**
Emergence	19.5
Tillering	16.8
Booting	20.2
Grain filling	23.4

K 9107 showed better tolerance to slight terminal heat stress, maintaining 1000-grain weight stability (44 g) compared to Sonalika (41 g). However, Sonalika's early maturity (≈118 days) allowed partial heat escape, reducing yield loss under delayed sowing.

Growing degree days (GDD) accumulated during crop season ranged between 1,650–1,780°C days, suitable for medium-duration wheat varieties.

Experimental Design **:** A statistically robust experimental framework was adopted to ensure scientific validity, precision of treatment comparison, and reproducibility under Assam's agro-climatic conditions.

Randomized Complete Block Design (RCBD) **:** The experiment was laid out in a **Randomized Complete Block Design (RCBD)** to control field variability arising from soil heterogeneity, micro-topography, and moisture gradients—common in alluvial soils of Assam. **Rationale for RCBD – a)** The experimental field showed slight fertility gradients (available N ranged 240–285 kg ha^{-1} across blocks), b) Soil pH variation across the site ranged from 4.9 to 5.6., c) RCBD minimizes experimental error by grouping similar experimental units into blocks.

Statistical Model:

$$Y_{ij} = \mu + T_i + B_j + \varepsilon_{ij}$$

Where: (Y_{ij}= observation of ith treatment in jth block, μ= overall mean, T_i= treatment effect, B_j= block effect, ε_{ij}= experimental error)

Precision Indicator - Coefficient of Variation (CV%) for grain yield was maintained below 8–10%, indicating high experimental reliability and Standard Error of Mean (SEm) ranged between 0.08–0.12 t ha^{-1}. RCBD ensured unbiased comparison between optimized agronomic practices and prevailing farmer practices.

Replications: Three replications were maintained to enhance statistical accuracy and reduce experimental error.

Justification are a) With two treatments and three replications, total experimental units = 6 plots per season, b) Replication increased degrees of freedom for error estimation, improving confidence in treatment comparisons, c) Statistical significance was tested at **$P = 0.05$** using ANOVA. Observed Variability:

Table No. 4

Parameter	**Mean**	**Standard Deviation**
Grain yield (t ha^{-1})	3.45	0.18
Tillers m^{-2}	400	21

The replication design reduced random variability due to a) Uneven soil moisture retention, b) Minor nutrient heterogeneity, c) Micro-climatic differences

Study Duration: Two Rabi Seasons

The study was conducted over **two consecutive rabi seasons**, ensuring – a) Validation under seasonal climatic variation, b) Stability analysis across years, c) Reduction of year-specific bias. **Seasonal Variability Observed:**

Table No. 5

Parameter	**Year 1**	**Year 2**
Seasonal rainfall (mm)	128	154
Mean temp (°C)	19.6	20.3
Yield (t ha^{-1}, mean)	3.38	3.52

The pooled analysis revealed – a) Yield advantage of optimized package: 22–26% across years, b) Stability Index (SI) >1.05 for optimized treatment, c) No significant treatment × year interaction at $P < 0.05$, Conducting multi-season trials strengthened inference reliability and climate resilience assessment.

Treatments : Two treatments were evaluated to compare scientific agronomic optimization with traditional farmer practice.

T_1: Optimized Package – the components are included in a) 120:60:40 kg $N:P_2O_5:K_2O$ ha^{-1}, b) Split nitrogen (basal + CRI + boot stage), c) Lime @ 2 t ha^{-1}, d) Timely sowing (15–30 November), e) Raised-bed planting in poorly drained plots, f) Seed treatment with fungicide and observed Impact:

Table No. 6

Parameter	**Value**
Grain yield (t ha^{-1})	3.82
Nitrogen Use Efficiency	38 kg grain/kg N
B:C Ratio	2.28

The optimized package enhanced as a) Tillers m^{-2} by 12–15%, b) 1000-grain weight by 6–8%, c) Protein content by 0.5–0.7%

T$_2$: Farmer Practice : Typical regional management are a) 70–80 kg N ha^{-1} (mostly basal), b) No liming, c) Flat sowing, d) Delayed planting (early December), e) Limited pest management and observed Output –

Table No.6

Parameter	**Value**
Grain yield (t ha^{-1})	3.05
Nitrogen Use Efficiency	28 kg grain/kg N
B:C Ratio	1.62

Lower productivity was associated with a) Nutrient imbalance, b) Reduced tillering, c) Higher disease incidence, d) Terminal heat exposure

Plot Size: 5 m × 4 m (20 m² Gross Plot Area)

Each experimental unit measured 20 m², adequate to a) Minimize border effects, b) Allow representative sampling, c) Facilitate agronomic operations and Plant population density maintained as a) Row spacing: 20 cm, b) Plant population: ~4.5–5.0 lakh plants ha^{-1}.

The plot size was statistically sufficient to estimate yield with acceptable precision while maintaining field manageability.

Net Harvest Area: 12 m²

To eliminate border influence, outer rows were excluded – a) Harvested area: central 12 m², b) Border rows removed: 0.5 m from all sides and **Reason for Net Plot Harvesting are a)** Prevent edge effect bias, b) Avoid nutrient and moisture interference from adjacent plots, c) Improve yield estimation accuracy. This ensured accurate and standardized yield computation.

Yield extrapolation formula: $Yield(tha^{-1}) = \frac{Plot\ yield\ (kg)}{12} \times 10{,}000$

Nutrient and Agronomic Management

The optimized nutrient and agronomic package was developed based on soil test values, regional recommendations for acidic soils of Northeast India, and physiological requirements of medium-duration wheat varieties. Each component was scientifically calibrated to enhance nutrient-use efficiency, stress tolerance, and yield stability under Assam's agro-climatic conditions.

Recommended Dose: 120:60:40 kg N:P_2O_5:K_2O ha⁻¹ - The fertilizer schedule was designed based on initial soil fertility status:

Table No. 7

Parameter	**Baseline Soil Status**
Available N	250–280 kg ha⁻¹
Available P_2O_5	14–18 kg ha⁻¹
Available K_2O	110–140 kg ha⁻¹

Scientific Rationale – a) Nitrogen (120 kg ha⁻¹): Supports tillering, chlorophyll synthesis, and grain protein formation, b) Phosphorus (60 kg ha⁻¹): Essential for root development and energy transfer (ATP), c) Potassium (40 kg ha⁻¹): Enhances stress tolerance and grain filling.

Table No. 8

Parameter	**Farmer Practice**	**Optimized**
Tillers m⁻²	350	405
Grain yield (t ha⁻¹)	3.05	3.82
Protein (%)	11.8	12.6

Balanced fertilization increased yield by 22–26% and improved grain protein content by ~0.8%.

a) Nitrogen Use Efficiency (NUE) – a) Farmer practice: 28 kg grain/kg N, b) Optimized: 38 kg grain/kg N

$$NUE = \frac{Grain\ Yield}{Applied\ N}$$

Split Nitrogen Application (3 Splits)

Nitrogen was applied in three stages – a) 50% basal (at sowing), b) 25% at Crown Root Initiation (CRI, 20–22 DAS), c) 25% at booting stage and as experimental Justification – a) Assam's soils experience leaching losses due to residual moisture, b) Split application synchronizes nitrogen availability with crop demand, c) Reduces volatilization and denitrification losses.

Physiological Benefit are a) CRI stage nitrogen increased effective tillers by 15%., b) Boot-stage application improved 1000-grain weight by 6%.

Split application improved nitrogen recovery efficiency by approximately 10–12% compared to single basal application.

Liming @ 2 t ha⁻¹ : Agricultural lime was applied 3–4 weeks before sowing and incorporated into the soil.

Baseline Soil Conditions: Table No. 9

Parameter	Before Liming
Soil pH	5.1
Exchangeable Al	0.65 cmol kg^{-1}
Available P	15 kg ha^{-1}

After Liming: Table No. 9a

Parameter	Value
Soil pH	6.0
Exchangeable Al	0.27 cmol kg^{-1}
Available P	22 kg ha^{-1}

Scientific Importance are a) Reduced aluminum toxicity by 58%., b) Improved phosphorus availability by ~48%., c) Enhanced root biomass and nutrient uptake . Yield improvement attributable to liming alone was approximately 0.35–0.45 t ha^{-1}.

Raised Bed Sowing in Lowlands

Raised beds (20 cm height; 60 cm bed width) were prepared in poorly drained fields.

Advantages in High-Rainfall Regions are a) Improved soil aeration, b) Reduced temporary waterlogging, c) Enhanced root penetration, d) Better fertilizer placement efficiency

Observed Results: Table No.10

Parameter	Flat Sowing	Raised Bed
Root length (cm)	14.5	18.2
Yield (t ha^{-1})	3.28	3.67
Water Use Efficiency	+15%	

Raised beds reduced yield loss due to excess moisture by 12–17%.

Seed Rate: 100 kg ha^{-1} : A seed rate of 100 kg ha^{-1} was maintained with 20 cm row spacing.

Target Plant Population are a) 4.5–5.0 lakh plants ha^{-1}, b) Germination percentage: 88–92%

Scientific Justification are a) Ensures optimum tiller development without excessive competition, b) Lower seed rate (<90 kg ha^{-1}) reduced plant stand, c) Higher seed rate (>120 kg ha^{-1}) increased lodging risk and reduced grain size. Optimized plant density contributed to a) 8–10% higher effective tillers, b) Uniform canopy development

Timely Sowing (15–30 November) : Sowing during the optimal window ensured proper synchronization with thermal regime.

Thermal Considerations: Table No.11

Sowing Date	**Grain Yield (t ha^{-1})**
20 November	3.85
5 December	3.42
15 December	3.05

Delay beyond 30 November are a) Increased exposure to terminal heat, b) Reduced grain filling duration by 6–8 days, c) Reduced yield by 10–18%

Timely sowing improved Growing Degree Day (GDD) utilization efficiency and enhanced grain weight stability.

Integrated Impact of Optimized Package

Table No. 12

Parameter	**Farmer Practice**	**Optimized Package**
Grain Yield (t ha^{-1})	3.05	3.82
Protein (%)	11.8	12.6
B:C Ratio	1.62	2.28
Net Return (₹ ha^{-1})	—	+19,800 to 21,500

The integrated nutrient and agronomic approach significantly enhanced as a) Yield stability, b) Nutrient use efficiency, c) Grain quality, d) Economic profitability, e) Climate resilience

Farmer Practice (Control Treatment): Baseline Production Scenario in Assam

The farmer practice treatment represented the prevailing wheat cultivation methods commonly adopted by small and marginal farmers in Assam. This management system reflects resource constraints, limited soil testing, and low external input use. The following components were critically evaluated to understand productivity gaps relative to the optimized package.

Nitrogen Application: 80 kg N ha^{-1} (Mostly Basal)

Under farmer practice, nitrogen was typically applied as a single basal dose (urea) at sowing, without phosphorus–potassium balance or split scheduling.

Field Observation Data – Table No. 13

Parameter	**Value**
Total N applied	80 kg ha^{-1}
Application method	Single basal
Nitrogen recovery efficiency	30–35%
Estimated N loss	25–40% (leaching + volatilization)

Scientific Implications are a) Basal-only application does not match crop demand during critical stages (CRI and booting), b) Acidic soils and residual moisture enhance nitrogen leaching losses, c) Reduced tiller formation due to inadequate N at CRI stage.

Yield Effect: Table No. 14

Parameter	**Farmer Practice**	**Optimized**
Tillers m^{-2}	350	405
Grain yield (t ha^{-1})	3.05	3.82
Protein (%)	11.8	12.6

Lower nitrogen dose and inefficient timing reduced by a) Effective tillers by ~13–15%, b) Grain protein by ~0.8%, c) Nitrogen Use Efficiency by ~10 kg grain/kg N

No Liming in Acidic Soils : Most farmers do not apply lime due to cost constraints and limited awareness.

Soil Conditions Without Liming - Table No. 15

Parameter	**Value**
Soil pH	5.0–5.2
Exchangeable Al	0.60–0.70 cmol kg^{-1}
Available P	14–16 kg ha^{-1}

Consequences are as a) Aluminum toxicity restricts root elongation, b) Phosphorus fixation increases under acidic conditions, c) Microbial activity and nutrient mineralization are suppressed.

Research observations showed as per a) 10–18% reduction in root biomass, b) 0.3–0.5 t ha^{-1} lower yield compared to limed plots, c) Reduced nutrient uptake efficiency. Without liming, phosphorus availability declined by nearly 30–40%, directly affecting early crop establishment.

Flat Sowing Method

Traditional flat sowing is widely practiced due to simplicity and lack of mechanized bed planters. Field Characteristics are a) Row spacing irregular (18–25 cm), b) Poor surface drainage in low-lying fields, c) Higher risk of temporary water stagnation

Observed Impact – Table No. 16

Parameter	**Flat Sowing**	**Raised Bed**
Root length (cm)	14.5	18.2
Lodging incidence (%)	12	5
Yield (t ha^{-1})	3.28	3.67

Flat sowing increased by a) Soil compaction, b) Reduced aeration, c) Nutrient runoff during winter showers. In water-prone areas, yield losses of 10–15% were recorded due to transient waterlogging.

Delayed Sowing (Early–Mid December): Farmers often sow wheat after harvesting late kharif crops such as rice or due to labor constraints.

Temperature Exposure – Table No. 17

Sowing Date	Grain Filling Temp (°C)	Yield (t ha⁻¹)
20 November	23.2	3.85
5 December	24.6	3.42
15 December	26.8	3.05

Physiological Effects are as a) Shortened grain filling period (by 6–8 days), b) Increased terminal heat stress, c) Reduced 1000-grain weight (41 g vs 44 g in timely sowing)

Delayed sowing reduced yield by 10–18% depending on seasonal heat accumulation. Growing Degree Day (GDD) accumulation declined by approximately 90–120°C days in late sowing, adversely affecting biomass partitioning.

Integrated Impact of Farmer Practice – Table No. 18

Parameter	Farmer Practice
Grain yield (t ha⁻¹)	3.05
Protein (%)	11.8
B:C Ratio	1.62
Net Return (₹ ha⁻¹)	Lower by ₹19,800–21,500

The cumulative effects of a) Suboptimal nitrogen dose, b) Absence of liming, c) Poor drainage management, d) Delayed sowing resulted in a 22–26% yield gap compared to the optimized package.

Scientific Interpretation : Farmer practice reflects a low-input, risk-averse production system. While cost of cultivation is lower, the system suffers from - a) Reduced nutrient-use efficiency, b) Lower grain quality, c) Higher vulnerability to climatic stress, d) Limited profitability. The productivity gap analysis clearly demonstrates that correcting soil acidity, optimizing nutrient scheduling, and ensuring timely sowing are the most impactful interventions for improving wheat performance in Assam.

Results and Discussion

Agronomic Performance – Table No. 19

Parameter	Sonalika	K 9107
Plant height (cm)	92	98
Days to maturity	118	124
Tillers m⁻²	390	410
1000-grain weight (g)	41.5	44.2
Grain yield (t ha⁻¹)	3.42	3.68

K 9107 showed superior grain weight and yield under cooler microclimates, while Sonalika performed better under terminal heat escape conditions.

Yield Improvement under Optimized Management

Table No. 20

Treatment	Yield (t ha^{-1})
Farmer Practice	3.05
Optimized Package	3.82

Yield increase: $\frac{3.82-3.05}{3.05} \times 100 = 25.2\%$

This aligns with findings that balanced fertilization enhances yield stability (ICAR-Wheat Directorate, 2021).

Soil Acidity Correction – Table No. 21

Parameter	Before Lime	After Lime
Soil pH	5.1	6.0
Available P (kg ha^{-1})	15	22
Yield (t ha^{-1})	3.18	3.62

Liming reduced aluminum toxicity and improved nutrient availability (Fageria & Baligar, 2008).

Disease Resistance – Table No. 22

Disease	Sonalika (%)	K 9107 (%)
Leaf Rust	9.5	5.2
Powdery Mildew	12.0	7.8

K 9107 demonstrated stronger resistance under humid conditions.

Grain Quality Analysis – Table No. 23

Parameter	Sonalika	K 9107
Protein (%)	12.1	12.8
Wet Gluten (%)	25.0	29.2
Gluten Index	70	84

K 9107 exhibited superior bread-making quality due to stronger gluten (Shewry & Hey, 2015).

Nutraceutical and Bioactive Compounds : Polyphenol content ranged between 210–260 mg GAE/100g.

Antioxidant activity (DPPH inhibition): **Table No. 24**

Variety	Inhibition (%)
Sonalika	34
K 9107	39

Phenolic antioxidants contribute to cardiovascular health benefits (Liu, 2013).

Industrial Suitability

Industrial Suitability of Sonalika and K 9107 Wheat Varieties

Industrial evaluation of wheat varieties is essential for value-chain development, market segmentation, and price realization. The suitability of wheat for bread, biscuits, and noodles depends primarily on protein content, gluten strength, gluten index, starch characteristics, and dough rheology. Laboratory baking and processing trials were conducted to assess end-use performance of *Sonalika* and *K 9107* under standardized conditions.

Bread-Making Quality : K 9107: Superior Loaf Volume (545 cc)

Loaf volume is a critical indicator of bread quality, reflecting gluten strength and gas retention capacity.

Table No. 25

Parameter	**Sonalika**	**K 9107**
Protein (%)	12.1	12.8
Wet Gluten (%)	25.0	29.2
Gluten Index	70	84
Loaf Volume (cc)	495	545

Scientific Interpretation are as it is a) K 9107 exhibited stronger gluten network formation due to higher glutenin-to-gliadin ratio, b) Higher gluten index (84) indicates strong dough elasticity and resistance to deformation, c) Gas retention during fermentation improved crumb structure and loaf height. A loaf volume of 545 cc falls within acceptable commercial bread standards (>500 cc). The higher protein (12.8%) contributed to improved dough development time and water absorption (~62%).

Industrial Implication: K 9107 is highly suitable for pan bread, fermented bakery products, and high-volume commercial baking.

Biscuit-Making Quality : Sonalika: Higher Spread Ratio (8.5)

Biscuit quality depends on weaker gluten strength to allow dough spread during baking.

Table No. 26

Parameter	**Sonalika**	**K 9107**
Gluten Strength	Moderate	Strong
Spread Ratio	8.5	7.2
Biscuit Diameter (mm)	65	58
Thickness (mm)	7.6	8.0

Scientific Explanation are as it is a) Moderate gluten strength in Sonalika reduces dough elasticity, b) Higher spread ratio (diameter/thickness) enhances crispness and texture, c) Excessively strong gluten (as in K 9107) restricts spread and results in harder biscuits.

Spread ratio of 8.5 is considered ideal for soft, crisp biscuits. Protein content around 12% is favorable for cookie-type products.

Industrial Implication: Sonalika is more suitable for biscuits, cookies, and confectionery applications.

Noodle and Pasta Quality : K 9107: Lower Cooking Loss (6.5%)
Cooking loss reflects structural integrity of starch-protein matrix during boiling.

Table No. 27

Parameter	**Sonalika**	**K 9107**
Cooking Loss (%)	8.2	6.5
Water Absorption (%)	135	128
Firmness (N)	4.8	5.6

Scientific Interpretation are as a) Stronger gluten matrix in K 9107 reduces starch leaching, b) Lower cooking loss (<7%) indicates better noodle firmness and reduced stickiness, c) Improved textural stability enhances consumer acceptance.

Cooking loss above 8% is considered suboptimal for premium noodle products; hence K 9107 demonstrates superior industrial quality.

Industrial Implication: K 9107 is suitable for noodles, pasta, and value-added wheat products requiring firm texture.

Functional and Rheological Properties

Farinograph analysis indicated: Table No. 28

Parameter	**Sonalika**	**K 9107**
Water Absorption (%)	58	62
Dough Development Time (min)	2.8	4.5
Stability (min)	4.2	7.8

Higher stability in K 9107 reflects better tolerance to mechanical mixing—an advantage for industrial-scale processing.

Economic and Market Implications : Quality-based segmentation allows as a) Premium pricing for bread-grade wheat (₹150–250 per quintal higher), b) Contract farming opportunities with bakery and noodle industries, c) Diversification into local processing enterprises.

Estimated value addition: Table No. 29

Product Type	**Price Advantage (₹/q)**
Bread-grade wheat	+200
Biscuit-grade wheat	+120
Noodle-grade wheat	+250

Assuming 3.5 t ha^{-1} yield, quality differentiation can enhance farmer income by ₹7,000–9,000 ha^{-1}.

Economic Analysis : Table No. 30

Practice	B:C Ratio
Farmer Practice	1.64
Optimized Package	2.31

Net income increase: ₹21,500 ha^{-1}, Higher profitability supports adoption feasibility.

Climate Resilience Assessment are as a) Yield stability index higher in K 9107, b) Raised beds reduced yield loss due to waterlogging by 17%, c) Integrated nutrient management increased soil organic carbon by 0.17%.

Policy and Development Implications are as 1. Promotion of liming subsidies in acidic regions, 2. Dissemination of small-scale seed drills, 3. Establishment of local wheat-based processing units, 4. Quality-based procurement pricing.

Conclusion

The present study on *"Integrated Agronomic, Nutritional, and Industrial Evaluation of Wheat Varieties Sonalika and K 9107 for Climate-Resilient Production and Food Security Enhancement in Assam"* establishes a comprehensive framework linking varietal performance with regional sustainability goals. The findings demonstrate that climate resilience in wheat cannot be evaluated solely on yield performance; rather, it requires an integrated assessment of agronomic adaptability, physiological tolerance, nutritional quality, and industrial suitability.

The evaluation confirms that **Sonalika**, owing to its early maturity and heat escape mechanism, performs relatively better under delayed sowing and terminal heat stress conditions common in Assam's agro-ecosystems. Its shorter crop duration allows it to avoid late-season temperature spikes, making it suitable for areas with constrained winter periods. Conversely, **K 9107** demonstrates superior grain quality characteristics, including better protein content and processing attributes, alongside stable yield performance under normal sowing conditions. Together, these varieties offer complementary strengths that can be strategically utilized across different agro-climatic niches of Assam.

From an agronomic perspective, the integration of timely sowing, optimized nutrient management, conservation tillage, and stress-monitoring tools enhances varietal performance under rising temperature scenarios. Physiological and biochemical indicators confirm that resilience is associated with maintenance of chlorophyll stability, efficient antioxidant defense mechanisms, and sustained grain filling duration.

Nutritional analysis indicates that both varieties possess acceptable protein levels and gluten quality suitable for household consumption and regional food processing industries. Industrial evaluation further reveals promising flour recovery and dough characteristics, creating opportunities for localized value addition and strengthening agro-based enterprises within Assam.

Policy Implications

1. **Climate-Smart Varietal Zonation Policy:** State agricultural departments should adopt agro-climatic zoning for varietal recommendation—promoting Sonalika in late-sown and short winter belts, and K 9107 in timely-sown irrigated tracts.
2. **Promotion of Region-Specific Seed Systems:** Establish certified seed multiplication programs within Assam to reduce dependency on external states and ensure timely availability of quality seeds.
3. **Integration with Food Security Programs:** Incorporate regionally adapted wheat varieties into public distribution and nutrition schemes to enhance protein intake and dietary diversification.
4. **Support for Wheat-Based Micro-Industries:** Encourage small-scale milling and baking industries using locally produced wheat to enhance farmer-market linkages and rural employment.
5. **Climate Adaptation Framework:** Integrate wheat improvement strategies into state climate action plans and climate-resilient agriculture missions.

Recommendations

1. **Adoption Strategy**
    a. Promote Sonalika in heat-prone and late-sown areas.
    b. Recommend K 9107 for stable environments requiring better grain quality.
2. **Agronomic Interventions**
    a. Timely sowing between mid-November and early December.
    b. Balanced fertilization with emphasis on nitrogen-use efficiency.
    c. Use of mulching and moisture conservation practices.
3. **Nutritional Enhancement**
    a. Encourage blending strategies in flour processing to optimize protein quality.
    b. Promote awareness of wheat's nutritional benefits among consumers.
4. **Research and Development**
    a. Further molecular characterization for heat tolerance markers.
    b. Development of stress indices integrating agronomic and quality parameters.
    c. Long-term multi-location trials under projected climate scenarios.

Suggestions for Future Research

1. Exploration of biofortification approaches to enhance micronutrient density.
2. Application of precision agriculture tools (remote sensing, canopy temperature monitoring).
3. Development of predictive models for yield stability under climate variability.
4. Assessment of carbon footprint and sustainability indices of wheat cultivation in Assam.

References

Reynolds, M. P., Braun, H. J., Pietragalla, J., & Ortiz, R. (2012).
Achieving yield gains in wheat through physiological breeding. *Journal of Experimental Botany*, 63(12), 4321–4335.
Shewry, P. R., & Hey, S. J. (2015).
The contribution of wheat to human diet and health. *Food and Energy Security*, 4(3), 178–202.
Braun, H. J., Atlin, G., & Payne, T. (2010).

Multi-location testing as a tool to identify climate-resilient wheat varieties. *Field Crops Research*, 119(1), 1–10.

Singh, G. P., Tiwari, V., & Kumar, A. (2019).

Improved wheat varieties and production technologies for eastern and northeastern India. *Indian Journal of Agricultural Sciences*, 89(4), 567–575.

Lal, R. (2016).

Climate change and sustainable food production. *Journal of Soil and Water Conservation*, 71(5), 139–148.

Gupta, P. K., Balyan, H. S., Sharma, S., & Kumar, R. (2020).

Genetics, genomics, and breeding of wheat for yield improvement and climate resilience. *Plant Breeding Reviews*, 43, 1–55.

Timsina, J., Singh, U., & Badaruddin, M. (2011).

Evaluation of agronomic practices for wheat production in South Asia. *Agricultural Systems*, 104(5), 429–438.