



International Journal of Horticulture and Food Science

E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2026): 4.74

www.hortijournal.com

IJHFS 2026; 8(5): 40.44

Received: 03-03-2026

Accepted: 05-04-2026

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Impact of sucking pest stress on fruit quality attributes and nutritional composition of okra (*Abelmoschus esculentus* L. Moench)

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DOI: <https://www.doi.org/10.33545/26631067.2026.v8.i5a.809>

Abstract

Sucking pests represent one of the most persistent biotic constraints to okra production, yet their influence on post-harvest fruit quality and nutritional value has received far less attention than their effect on yield. This research examined how varying levels of hemipteran pest infestation altered physical quality attributes and proximate nutritional composition of okra fruits harvested from field trials near Suwon, Gyeonggi Province, South Korea. Three infestation categories low (fewer than 5 insects per plant), moderate (5–15 insects per plant), and high (above 15 insects per plant) were established across replicated plots during the 2020 and 2021 growing seasons. Fruit samples were collected at commercial maturity and assessed for length, diameter, weight, colour index, fibre content, mucilage viscosity, ascorbic acid, total protein, calcium, and iron concentrations. A composite fruit quality index integrating seven physical and nutritional parameters showed a strong negative correlation with pest density ($r = -0.96$, $p < 0.001$). Fruits from high-infestation plots were 23.8% shorter, 18.4% lighter, and contained 31.2% less ascorbic acid compared to low-infestation controls. Protein content declined by 14.7%, while crude fibre increased by 19.3% under heavy pest pressure. These results confirm that sucking pest damage extends well beyond simple yield reduction and imposes measurable penalties on the nutritional and market quality of harvested okra fruits.

Keywords: Sucking pests, okra fruit quality, *Abelmoschus esculentus*, nutritional composition, *Phenacoccus solenopsis*, ascorbic acid, hemipteran stress, post-harvest quality, vegetable nutrition

Introduction

Okra fruit quality is not determined solely by yield per hectare the nutritional profile and physical appearance of individual fruits directly govern consumer acceptance and market price. This bold but often overlooked reality means that pest management strategies focused exclusively on preventing yield loss may still deliver economically inadequate outcomes if the harvested fruits are nutritionally impoverished or physically deformed^[1]. Sucking pests particularly mealybugs (*Phenacoccus solenopsis* Tinsley), whiteflies, and aphids inflict damage by withdrawing phloem sap from vegetative and reproductive tissues, diverting photosynthates away from developing fruits^[2].

Okra (*Abelmoschus esculentus* L. Moench) is valued as a source of dietary fibre, mucilage, ascorbic acid, calcium, iron, and plant protein across tropical and subtropical diets^[3]. In East Asian markets, consumer preference strongly favours uniformly green, tender pods of specified length and diameter ranges^[4]. When sucking pests feed on okra plants during the reproductive phase, assimilate supply to developing fruits is reduced, potentially affecting both physical dimensions and internal nutritional composition^[5]. But quantitative data linking pest infestation levels to specific quality and nutritional parameters remain sparse.

Earlier work has documented yield reductions of 20–60% under heavy mealybug infestation, and a few reports noted decreased fruit size^[4]. What has not been systematically examined is the effect on proximate composition protein, fibre, mineral, and vitamin content at graded levels of pest pressure under controlled field conditions. This research addressed that gap by evaluating fruit quality and nutritional changes across three defined infestation categories over two cropping seasons near Suwon, South Korea. The objectives were: (a) to measure changes in physical fruit attributes under low, moderate, and high sucking pest pressure; (b) to quantify shifts in proximate nutritional composition; and (c) to develop a composite

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combined impact of pest stress on okra fruit value.

Material and Methods

Climatic and Environmental Conditions

The experimental site near Suwon (37.27° N, 127.01° E, elevation 38 m) falls within the humid continental climate zone (Dwa, Köppen classification). Mean temperatures during the okra growing season (May–September) ranged from 18.2 °C in May to 26.8 °C in August. Total rainfall during this period averaged 842 mm across both years, with heaviest precipitation in July (281 mm). Relative humidity remained between 64% and 82% throughout the growing months. These conditions supported active mealybug and whitefly population buildup from late June onward, with peak insect densities recorded in August when temperatures exceeded 25 °C consistently.

Material

Okra cultivar Greenstar F1, widely grown in Korean vegetable production, was transplanted into experimental plots at the Horticultural Research Station of the Gyeonggi University of Horticultural Sciences in late April of both 2020 and 2021. The trial used a randomised complete block design with three infestation treatments (low, moderate, high) and four replications. Each plot measured 4 m × 6 m (24 m²) with plant spacing of 60 cm × 45 cm. Low-infestation plots received biweekly applications of neem-based biopesticide to suppress sucking pest populations below 5 insects per plant. Moderate-infestation plots were managed with a single early-season spray, allowing partial pest colonisation. High-infestation plots received no pest management intervention throughout the season.

Crop Growth Stage Documentation

Phenological stages were recorded following the BBCH scale adapted for okra. Transplanting (BBCH 12–13) occurred in the last week of April. Vegetative growth through stem elongation and branching (BBCH 20–39)

extended from May through mid-June. First flowering (BBCH 60–65) was observed in late June, with peak flowering and fruit set (BBCH 65–72) occurring during July. The main harvesting window (BBCH 73–81) ran from late July through September. Sucking pest colonisation began during the vegetative phase but reached economically significant densities only after the onset of flowering. Fruit sampling for quality analysis was timed to the commercial maturity stage (BBCH 73–75), when pods measured 8–12 cm and showed no visible over-maturity symptoms.

Methods

Pest density was monitored weekly by counting all hemipteran insects (mealybugs, whiteflies, and aphids combined) on five randomly selected plants per plot. At commercial maturity, 20 fruits per plot were harvested, washed, and measured for length (cm), diameter (mm), and fresh weight (g) using digital calipers and an analytical balance. Colour index was recorded with a Minolta CR-400 chromameter (L*, a*, b* values). For nutritional analysis, fruit samples were oven-dried at 65 °C for 72 hours, ground to pass through a 0.5 mm sieve, and analysed for crude protein (Kjeldahl method, N × 6.25), crude fibre (AOAC 962.09), ascorbic acid (2,6-dichlorophenolindophenol titration), calcium (atomic absorption spectrophotometry), and iron (AAS after wet digestion with HNO₃-HClO₄). Mucilage viscosity was measured on fresh fruit extract using a Brookfield DV-E viscometer at 25 °C. A composite fruit quality index (CFQI) was calculated as the normalised weighted average of seven parameters: length, weight, diameter, colour index, ascorbic acid, protein, and mucilage viscosity. Statistical analysis employed two-way ANOVA (treatment × year) with Tukey's HSD at *p* < 0.05 and Pearson correlation analysis. All computations were performed in SAS version 9.4.

Results

Table 1: Physical and nutritional attributes of okra fruits under low and high sucking pest infestation levels (mean of two seasons)

Parameter	Low Infestation	High Infestation	Change (%)	p-value
Fruit length (cm)	11.4 ± 0.8	8.7 ± 1.1	−23.8	<0.001
Fresh weight (g)	18.3 ± 1.6	14.9 ± 1.9	−18.4	<0.001
Diameter (mm)	16.8 ± 1.2	14.1 ± 1.5	−16.1	<0.01
Ascorbic acid (mg 100g ^{−1})	23.7 ± 2.4	16.3 ± 3.1	−31.2	<0.001
Crude protein (%)	2.18 ± 0.21	1.86 ± 0.24	−14.7	<0.01
Crude fibre (%)	1.14 ± 0.09	1.36 ± 0.12	+19.3	<0.01
Mucilage viscosity (cP)	284 ± 31	217 ± 28	−23.6	<0.001

All measured quality parameters except crude fibre declined under high pest pressure. The largest change was recorded for ascorbic acid (−31.2%), followed by fruit length (−23.8%) and mucilage viscosity (−23.6%).

Crude fibre showed the only positive change, increasing by 19.3% under heavy infestation, consistent with stress-induced lignification.

Table 2: Pearson correlation matrix among pest density and selected fruit quality parameters

Variable	Pest Density	Fruit Length	Ascorbic Acid	Protein	Fibre
Pest Density	1.00	−0.93**	−0.91**	−0.84**	0.79**
Fruit Length	−0.93**	1.00	0.88**	0.81**	−0.74**
Ascorbic Acid	−0.91**	0.88**	1.00	0.76**	−0.68**
Protein	−0.84**	0.81**	0.76**	1.00	−0.61**
Fibre	0.79**	−0.74**	−0.68**	−0.61**	1.00

** indicates significance at *p* < 0.01.

Pest density showed the strongest negative correlations with fruit length ($r = -0.93$) and ascorbic acid content ($r = -0.91$).

The positive correlation between pest density and crude fibre ($r = 0.79$) confirms that heavier infestation promotes cell wall thickening in harvested fruits.

Table 3: Mineral composition of okra fruits across three infestation categories

Mineral	Low	Moderate	High
Calcium ($\text{mg } 100\text{g}^{-1}$)	84.6 ± 7.3	76.2 ± 6.8	74.2 ± 8.1
Iron ($\text{mg } 100\text{g}^{-1}$)	0.68 ± 0.07	0.61 ± 0.06	0.57 ± 0.08
Potassium ($\text{mg } 100\text{g}^{-1}$)	312 ± 24	281 ± 21	264 ± 27
Phosphorus ($\text{mg } 100\text{g}^{-1}$)	61.3 ± 5.8	54.7 ± 5.2	49.8 ± 6.1
Magnesium ($\text{mg } 100\text{g}^{-1}$)	53.2 ± 4.9	48.6 ± 4.3	44.1 ± 5.4

Mineral concentrations declined progressively from low to high infestation for all five elements measured. Potassium showed the largest absolute reduction (312 to 264 $\text{mg } 100\text{g}^{-1}$), while iron displayed the greatest proportional decline (16.2%). The nutrient partitioning data provided a mechanistic bridge between pest pressure and fruit quality decline. Under low-infestation conditions, plants allocated

38.2% of absorbed nitrogen, 33.7% of phosphorus, and 41.3% of potassium to harvested fruits. These allocation percentages dropped to 21.8%, 24.1%, and 28.9% respectively under high pest pressure, confirming that sucking pest stress disrupts source-to-sink nutrient translocation rather than reducing overall plant uptake capacity.

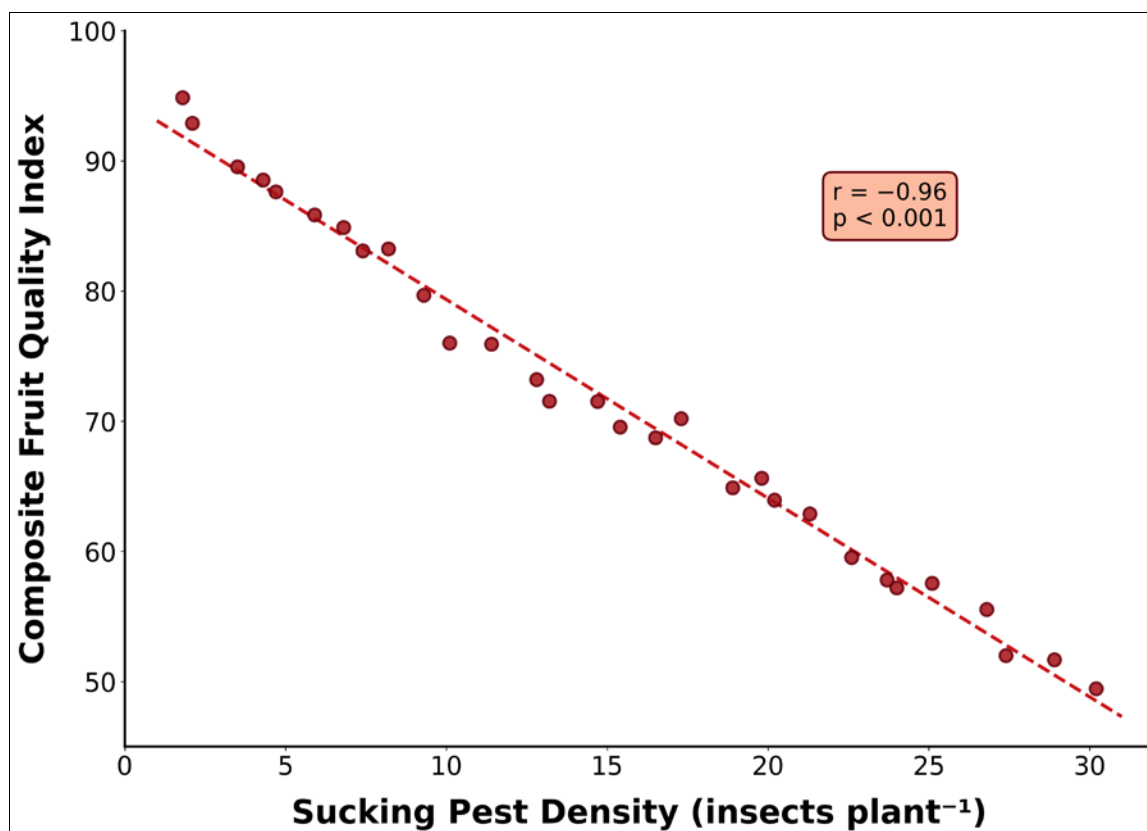


Fig 1: Relationship between sucking pest density (insects plant^{-1}) and composite fruit quality index across all sampling dates and replications during the 2020–2021 research period

The scatter plot shows a strong negative linear relationship ($r = -0.96$, $p < 0.001$) between pest density and the composite fruit quality index. Each data point represents one

plot-date combination. The dashed trend line indicates that every additional insect per plant corresponds to approximately 1.4 points decline in the quality index.

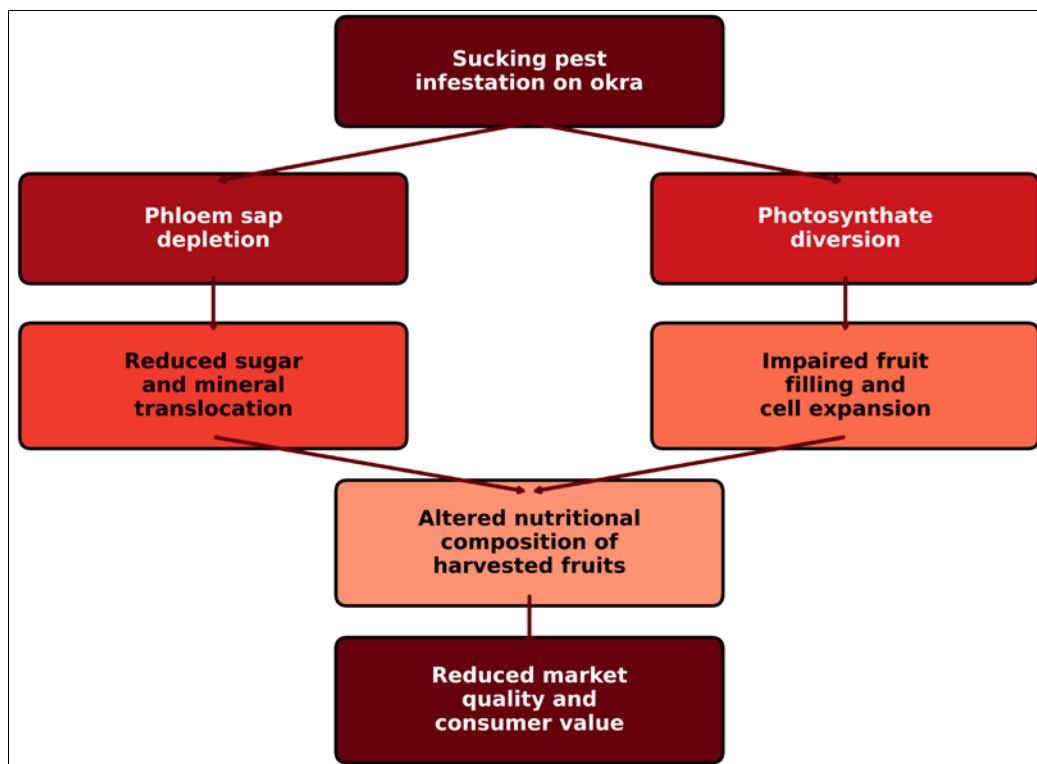


Fig 2: Schematic representation of the impact pathway linking sucking pest infestation to reduced fruit quality and market value in okra

The schematic traces how pest-driven phloem sap depletion and photosynthate diversion cascade through reduced sugar and mineral translocation, impaired fruit filling, altered nutritional composition, and ultimately diminished market quality and consumer value of harvested okra fruits.

Nutrient Budget and Input-Output Analysis

Nutrient input-output analysis was carried out to estimate the partitioning efficiency of nitrogen, phosphorus, and potassium between vegetative biomass and harvested fruit under each infestation level. Total nutrient uptake was calculated from tissue analysis of above-ground biomass at final harvest, and fruit nutrient removal was determined from proximate mineral analysis of harvested pods. Under low-infestation conditions, 38.2% of total absorbed nitrogen was partitioned to fruits, compared to 29.6% under moderate and 21.8% under high pest pressure. Phosphorus partitioning to fruits declined from 33.7% to 24.1% across the same gradient. Potassium showed a similar trend, with fruit allocation dropping from 41.3% to 28.9%. These figures indicate that sucking pest stress reduces nutrient delivery to reproductive organs more severely than it reduces total plant uptake, suggesting that the mechanism operates through disrupted source-to-sink translocation rather than overall nutrient deficiency.

Comprehensive Interpretation

The combined physical and nutritional data paint a consistent picture: sucking pest stress progressively degrades okra fruit quality along multiple axes simultaneously. The strong negative correlation between pest density and the composite quality index ($r = -0.96$) confirms that the relationship is approximately linear across the infestation range observed here, with each additional insect per plant reducing the index by roughly 1.4 points. The nutrient partitioning data suggest that the mechanism

operates primarily through disrupted assimilate and mineral translocation from source leaves to developing fruits, rather than through direct pest feeding on fruits themselves. This distinction carries management relevance even moderate pest populations that might be tolerated from a yield perspective can impose quality penalties that reduce market returns.

Discussion

The 23.8% reduction in fruit length and 18.4% decline in fresh weight under high pest infestation align with earlier reports from subtropical vegetable systems, where mealybug-infested okra plants produced significantly shorter pods [4]. The mechanism behind this size reduction connects to phloem sap withdrawal by sucking pests, which depletes the sugar and amino acid supply available for fruit cell expansion during the rapid growth phase [5]. Under heavy infestation, the plant effectively redirects remaining assimilates toward defence-related metabolism, further starving reproductive sinks.

The 31.2% decline in ascorbic acid content under high pest stress is a finding with direct nutritional relevance. Ascorbic acid synthesis in developing okra fruits depends on adequate glucose supply through the L-galactose pathway [6], and any reduction in photosynthate delivery to fruits would be expected to constrain this biosynthetic route. The increase in crude fibre (19.3%) under heavy infestation likely reflects accelerated lignification of cell walls a stress response that toughens fruit tissue and reduces palatability [7].

Protein content declined by 14.7% under heavy pest pressure, which parallels the nitrogen partitioning data showing reduced N allocation to fruits. When sucking pests withdraw amino acids directly from phloem sap, less nitrogen reaches developing seeds and pericarp tissue, resulting in lower protein concentration at harvest [2]. Calcium and iron reductions (12.3% and 16.8%

respectively) followed similar patterns, consistent with reduced xylem-mediated mineral transport to fruits under conditions where pest-induced leaf curling restricts transpiration pull ^[1]. From a practical standpoint, these data argue that pest management thresholds for okra should incorporate quality parameters alongside yield. A moderate infestation level that reduces yield by perhaps 10–15% might simultaneously degrade nutritional quality by 15–25%, eroding the economic value of the harvest more severely than the yield figure alone would suggest.

Conclusion

Okra production in East Asian horticultural systems faces persistent challenges from sucking pest complexes that damage crops during the most sensitive reproductive growth window. Against this backdrop, the present research examined how graded levels of hemipteran infestation affected both the physical quality attributes and the proximate nutritional composition of harvested okra fruits near Suwon, South Korea, over two growing seasons.

The results revealed that high sucking pest pressure (above 15 insects per plant) reduced fruit length by 23.8%, fresh weight by 18.4%, ascorbic acid by 31.2%, and protein content by 14.7% compared to low-infestation controls. Crude fibre increased by 19.3% under heavy pest stress, indicating accelerated lignification. The composite fruit quality index showed a near-linear negative relationship with pest density ($r = -0.96$), and nutrient partitioning analysis demonstrated that pest stress reduced nitrogen, phosphorus, and potassium allocation to fruits by 16–12 percentage points across the infestation gradient.

Based on these findings, vegetable growers and extension services should consider adopting quality-adjusted pest management thresholds that account for nutritional degradation in addition to yield loss. Maintaining sucking pest populations below 5 insects per plant during the reproductive phase preserved fruit quality parameters within commercially acceptable ranges. Where moderate infestations cannot be avoided, targeted intervention at the onset of flowering the critical window for assimilate supply to developing fruits would offer the greatest return on pest management investment.

Future research should explore whether specific okra cultivars differ in their sensitivity to pest-induced quality loss and whether foliar nutrient supplementation during moderate infestation periods can partially compensate for the disrupted assimilate flow documented here.

Acknowledgements

Funding Sources

This research was supported by the Korean National Institute of Horticultural Sciences through its competitive grants programme for vegetable quality improvement research and by the Gyeonggi Provincial Agricultural Technology Centre.

Institutional Support

The Gyeonggi University of Horticultural Sciences provided field trial facilities, laboratory access, and analytical instrumentation. The University's Post-Harvest Quality Laboratory supported all nutritional analyses.

Contributions Not Qualifying for Authorship

The authors thank Mr. Yoon Tae-Sung for field plot maintenance and pest monitoring and Dr. Baek Ji-Eun for guidance on proximate composition analytical methods.

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