International Journal of Advanced Agriculture and Research

ISSN: 3121-6420

Volume 2, Issue 2 | April, 2026

(An Academians Publishers of Research & Academic Resources)

Review Article

Received: 28-02-2026 Accepted: 18-03-2026 Published: 28-04-2026

Bridging the Gap: Integrating Soil Health Management into Agricultural Curricula to Enhance Sustainable Agriculture Knowledge and Practices

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Abstract: Soil health management is fundamental to sustainable agriculture, yet a significant gap exists between scientific knowledge of soil restoration practices and the awareness and competencies of future agricultural professionals. This research synthesis paper integrates findings from two complementary studies: one outlining evidence-based soil health management strategies for semi-arid environments, and another assessing sustainable agriculture knowledge and sustainable nutrition behaviors among Faculty of Agriculture students. The synthesis reveals that while students demonstrate moderate overall knowledge of sustainable agriculture (mean score 34.43 ± 10.11 on a 55-point scale) and high awareness of the concept (95.1%), significant deficiencies exist in specific areas critical to soil health—particularly compost and biofertilizer applications (lowest item score, 2.91 ± 1.20) and soil health maintenance (2.99 ± 0.99). Furthermore, significant departmental differences in knowledge scores ($p = 0.01$) indicate uneven curriculum coverage of sustainability principles. This paper proposes an integrated framework aligning soil health management strategies—including regular soil testing, organic matter rehabilitation, integrated nutrient management (INM), biofertilizer deployment, and green manuring—with targeted curriculum interventions for agricultural education. Recommendations include strengthening course content on soil microbiology, composting systems, and microbial solutions; implementing practice-based training modules; and fostering interdisciplinary approaches that connect soil health to sustainable nutrition behaviors. The synthesis argues that closing the knowledge-practice gap in soil health education is essential for preparing future agricultural professionals to address climate resilience, food security, and land degradation challenges.

Keywords: *Soil health management, sustainable agriculture education, agricultural curricula, biofertilizers, integrated nutrient management, sustainable nutrition,*

1. Introduction

The degradation of agricultural soils represents one of the most pressing yet underrecognized challenges to global food security. As Choudhary and Choudhary (2026) articulate in their comprehensive review of soil health management, the conventional treatment of soil as inert "dirt"—a passive medium for seed placement rather than a living ecosystem—has accelerated soil exhaustion, particularly in harsh semi-arid environments where moisture scarcity and heat stress intensify degradation processes. The authors argue that managing soil health is not merely another task on a farmer's agenda but rather the ultimate investment in farm longevity and productivity.

Simultaneously, the educational preparation of future agricultural professionals has come under increasing scrutiny. Kumru Akın and Palabıçak (2026), in their assessment of Faculty of Agriculture students at Harran University, Turkey, documented moderate but uneven knowledge levels regarding sustainable agriculture, with particular gaps in areas directly related to soil biological management. Their study of 145 students revealed that while 95.1% had heard of sustainable agriculture, only 62.7% were familiar with sustainable nutrition, and specific knowledge items—such as the contribution of compost or biofertilizer use to sustainable agriculture—received the lowest scores.

This paper synthesizes these two bodies of work to address a critical question: How can evidence-based soil health management strategies be effectively integrated into agricultural curricula to enhance the knowledge and preparedness of future agricultural professionals? The synthesis is timely given the convergence of climate change, land degradation, and the need for a generational transition in agricultural practices toward sustainability.

The specific objectives of this synthesis paper are:

- To distill core soil health management principles from Choudhary and Choudhary (2026) that are essential for agricultural education;
- To analyze the knowledge gaps identified by Kumru Akın and Palabıçak (2026) in relation to these soil health principles;
- To propose an integrated curriculum framework that addresses identified deficiencies; and
- To recommend pedagogical approaches that bridge theoretical knowledge with practical competencies.

2. Literature Review

2.1 Soil Health as a Living Ecosystem

The foundational premise of modern soil science, as articulated by Choudhary and Choudhary (2026), is that soil functions as a living, breathing ecosystem rather than an inert substrate. This perspective transforms the management paradigm from extraction to stewardship. Under semi-arid conditions—characterized by annual rainfall below 400 mm, high evapotranspiration rates, and temperature extremes—soil health degradation proceeds rapidly unless deliberate management interventions are implemented.

Soil health encompasses three interdependent dimensions: physical (structure, porosity, water infiltration and retention), chemical (pH, electrical conductivity, nutrient availability, absence of toxicity), and biological (microbial biomass, diversity, activity, soil food web functionality). Mamatha et al. (2024) emphasize that these dimensions are not separable; interventions targeting one dimension inevitably affect the others. For example, adding organic matter improves physical structure while simultaneously feeding microbial communities and buffering chemical extremes.

2.2 Core Soil Health Management Strategies

Choudhary and Choudhary (2026) organize soil health management into five strategic domains, each supported by mechanistic soil processes and on-farm outcomes:

Regular Soil Testing: Described as the foundational diagnostic tool, soil testing eliminates guesswork by quantifying pH, electrical conductivity (indicating salt buildup), and macronutrient (N, P, K) and micronutrient availability. This enables targeted fertilizer applications that reduce economic losses from unnecessary inputs while preventing acidification, salinization, and nutrient runoff associated with over-fertilization.

Organic Matter Rehabilitation: Organic matter—derived from decomposed plant residues, farmyard manure, and compost—functions as the "beating heart" of soil fertility. In semi-arid environments, organic matter acts as a subsurface sponge, dramatically improving water-holding capacity. Beyond moisture retention, it provides slow-release nutrients and creates aerated structure for root penetration.

Integrated Nutrient Management (INM): INM represents a balanced approach combining chemical fertilizers (providing immediate nutrient pulses when crops need them most) with organic sources such as green manure, compost, and crop residues. This dual strategy feeds both the current crop and future soil, maximizing yields while minimizing ecological damage.

Biofertilizers and Microbial Solutions: Beneficial microorganisms—including nitrogen-fixers (Rhizobium, Azotobacter), phosphate solubilizers (PSB), and mycorrhizal fungi—constitute an invisible workforce. Biofertilizers introduce these organisms to seeds or soil, harnessing natural processes for nutrient provision and root system extension.

Land Remediation: For degraded lands affected by erosion, crusting, salinity, or alkalinity, strategic interventions including gypsum amendments and green manuring with deep-rooted cover crops (e.g., Dhaincha/Sesbania) can restore productivity. This approach shifts the paradigm from extraction to active rehabilitation.

2.3 Sustainable Agriculture Education: Knowledge and Behavior Dimensions

The study by Kumru Akın and Palabıçak (2026) provides empirical data on how well agricultural students understand sustainability concepts. Conducted with 145 students across six departments at Harran University, the study utilized the Sustainable Agriculture Knowledge Level (SAKL) survey (11 items, 5-point Likert, range 11–55) and the Sustainable Nutrition Behavior Scale (SNBS) (29 items, 4 subscales).

Key findings include:

- Mean SAKL score: 34.43 ± 10.11 (theoretical mid-point 33, indicating moderate knowledge)
- Highest-scoring item: knowledge of water-saving methods (drip irrigation) (3.31 ± 1.01)
- Lowest-scoring item: awareness of compost/biofertilizer contribution (2.91 ± 1.20)
- Significant departmental differences ($p = 0.01$): Plant Protection students scored highest (42.38 ± 10.14); Soil Science and Plant Nutrition students scored lowest (28.00 ± 10.23)
- Significant grade-level differences ($p = 0.01$): Fourth-year students (38.49 ± 10.04) outperformed first-year students (29.76 ± 11.02)

- Positive correlation between SAKL and sustainable nutrition behaviors ($r = 0.44$, $p < 0.001$), with strongest correlation for food preference subdimension ($r = 0.47$)

These findings reveal a paradoxical situation: agricultural students are broadly aware of sustainable agriculture but lack depth in critical areas, particularly soil biological management (compost, biofertilizers). Moreover, the significant departmental differences suggest that sustainability knowledge is not uniformly integrated across curricula.

2.4 The Gap Between Soil Health Science and Agricultural Education

When juxtaposing the two source documents, a concerning gap emerges. The soil health strategies detailed by Choudhary and Choudhary (2026)—soil testing interpretation, organic matter management, INM balancing, biofertilizer application protocols, and green manuring techniques—represent precisely the knowledge domains where Kumru Akın and Palabıçak (2026) documented student deficiencies. The lowest-scoring SAKL item (compost/biofertilizer contribution) corresponds directly to a core soil health intervention. Similarly, the relatively low score for soil health maintenance knowledge (2.99 ± 0.99) indicates that even fundamental soil stewardship principles are not adequately transmitted.

This gap is not merely academic. As Choudhary and Choudhary (2026) warn, without deliberate intervention, soils under continuous cropping and heat stress lose vitality, compact, and become vulnerable to wind and water erosion. Future agricultural professionals who do not understand soil biological processes will be ill-equipped to reverse this trajectory.

3. Methodology of the Synthesis

This paper employs a qualitative synthesis methodology, integrating two distinct but complementary source documents. The first source (Choudhary & Choudhary, 2026) is a practice-oriented integrative review of soil health management strategies, drawing on agronomic science and field-based evidence. The second source (Kumru Akın & Palabıçak, 2026) is a cross-sectional descriptive study using validated survey instruments (SAKL and SNBS) with 145 participants.

The synthesis approach involved:

- Extracting core soil health management principles from the first source;
- Mapping these principles to specific knowledge items assessed in the SAKL survey;
- Identifying knowledge gaps from the second source;
- Analyzing departmental and grade-level differences to pinpoint curriculum weak points;
- Deriving an integrated framework for curriculum enhancement.

This synthesis does not replicate original data collection but rather performs secondary analysis of published findings to generate new insights at the intersection of soil science and agricultural education.

4. Integrated Findings: Mapping Soil Health Strategies to Student Knowledge Gaps

4.1 Soil Testing and Diagnostic Knowledge

Choudhary and Choudhary (2026) position regular soil testing as the primary diagnostic tool, enabling farmers to understand pH, electrical conductivity, and nutrient availability before applying amendments. The SAKL survey includes a general item on "methods for maintaining soil health" (2.99 ± 0.99) but does not specifically assess knowledge of soil test interpretation. The moderate score suggests that students recognize soil health as important but lack specific diagnostic competencies. This represents a curriculum gap: teaching soil testing procedures without emphasizing interpretation skills creates a superficial understanding.

4.2 Organic Matter Management: The Most Critical Gap

The most striking finding from the student assessment is that awareness of "the contribution of compost or biofertilizer use to sustainable agriculture" received the lowest mean score (2.91 ± 1.20) of all 11 SAKL items. This is precisely the domain that Choudhary and Choudhary (2026) identify as the "beating heart" of soil fertility. The authors describe organic matter as transforming lifeless dust into rich, crumbly earth, acting as an underground sponge for water retention, and providing slow-release nutrients.

The low score on this item is consistent across departments, though with variation. Even in the Plant Protection department—the highest-scoring group overall (42.38)—specific knowledge of compost and biofertilizers may be underdeveloped. The Soil Science and Plant Nutrition department, paradoxically, scored lowest overall (28.00) despite this department being most directly responsible for soil biological education. This paradox suggests that current curricula emphasize soil chemistry and physics over soil biology and organic matter dynamics.

4.3 Integrated Nutrient Management (INM) Understanding

The SAKL item on "effects of fertilizer use on sustainable agriculture" scored 3.13 ± 1.13—close to the scale midpoint but not high. Choudhary and Choudhary (2026) advocate INM as a balanced diet for soil, combining chemical fertilizers (immediate nutrition) with organic sources (long-term conditioning). Student responses suggest that they may understand the risks of over-fertilization (the item on environmental impacts of chemical pesticides scored higher at 3.33 ± 1.13) but lack a nuanced understanding of how to integrate synthetic and organic inputs strategically.

4.4 Biofertilizers and Microbial Solutions

The item on compost/biofertilizer contribution (lowest score) directly aligns with Choudhary and Choudhary's (2026) discussion of biofertilizers and microbial solutions. The authors describe nitrogen-fixing bacteria (Rhizobium, Azotobacter), phosphate solubilizers (PSB), and mycorrhizal fungi as an "invisible workforce" that can be harnessed through biofertilizer formulations. The low student scores indicate that despite the scientific consensus on microbial contributions to sustainable agriculture (see also Choudhary et al., 2020; Lal et al., 2021), this content is not effectively reaching agricultural students.

4.5 Departmental Differences: A Curriculum Signal

The significant departmental differences ($p = 0.01$) documented by Kumru Akın and Palabıçak (2026) provide actionable intelligence for curriculum reform. Students in Plant Protection scored highest (42.38 ± 10.14), followed by Agricultural Structures and Irrigation (35.74 ± 9.16), Field Crops (35.63 ± 10.99), and Garden Plants (34.58 ± 10.91). The lowest scores were in Agricultural Economics (32.82 ± 8.69) and Soil Science and Plant Nutrition (28.00 ± 10.23).

The low score in Soil Science and Plant Nutrition is particularly concerning, as this department should be the institutional home for soil health expertise. One possible explanation is that the curriculum emphasizes classical soil science (mineralogy, classification, chemistry) over applied soil health management (organic matter dynamics, microbial ecology, composting systems). Alternatively, the small sample size (n=12) for this department may limit reliability, but the finding warrants investigation.

The high score in Plant Protection is understandable given that integrated pest management (IPM)—a core component of sustainable agriculture—is central to that department's curriculum. However, IPM focuses primarily on pest and disease management rather than soil health per se. The higher overall knowledge may reflect general environmental awareness rather than specific soil competencies.

4.6 Grade-Level Progression: Evidence of Curriculum Impact

The significant grade-level difference ($p = 0.01$) demonstrates that agricultural education does increase sustainable agriculture knowledge over time. Fourth-year students scored substantially higher (38.49 ± 10.04) than first-year students (29.76 ± 11.02). This is encouraging, indicating that courses taken during the program contribute to knowledge gains. However, even fourth-year students scored only 38.49 out of 55 (70% of maximum), suggesting room for improvement. Moreover, the specific gap in compost/biofertilizer knowledge may persist even at higher grade levels; the original study did not report item-level scores by grade.

5. Discussion

5.1 The Soil Health Knowledge Deficit: Causes and Consequences

The synthesis reveals a concerning disconnect between the scientific consensus on soil health management and the knowledge levels of agricultural students who will become extension agents, farm advisors, agribusiness professionals, and policymakers. While students demonstrate general awareness of sustainable agriculture—95.1% have heard the term—their specific knowledge of soil biological management, composting, and biofertilizers remains shallow.

Several factors may explain this deficit. First, agricultural curricula traditionally emphasize yield-maximizing technologies (high-yielding varieties, synthetic fertilizers, pesticides) over soil stewardship. Bijarnia et al. (2020) noted that even emerging approaches like Zero Budget Natural Farming receive limited attention in mainstream agricultural education. Second, soil biology and composting are often taught as theoretical concepts without hands-on laboratory or field components, reducing knowledge retention and practical competency. Third, the rapid expansion of agricultural technology (drones, sensors, precision agriculture) may divert attention from foundational soil processes.

The consequences of this knowledge deficit are not hypothetical. Choudhary and Choudhary (2026) warn that without organic matter rehabilitation, soils under semi-arid conditions compact, harden, and become vulnerable to wind erosion. Tahat et al. (2020) demonstrated that soil health degradation directly reduces crop water use efficiency, increases fertilizer requirements, and diminishes yield stability under drought stress. Agricultural professionals who do not understand these relationships cannot effectively advise farmers or design sustainable production systems.

5.2 The Sustainable Agriculture–Sustainable Nutrition Nexus

An additional contribution of the student assessment study is the documented positive correlation between sustainable agriculture knowledge and sustainable nutrition behaviors ($r = 0.44$, $p < 0.001$). While the focus of this synthesis is soil health, the correlation has implications for curriculum design. Students who understand sustainable agriculture principles (including soil health) are more likely to adopt sustainable food preferences, reduce food waste, and choose seasonal/local foods.

Choudhary and Choudhary (2026) did not address nutrition directly, but the linkage is logical: soil health affects crop nutrient density. Depleted soils produce crops with lower micronutrient content, contributing to "hidden hunger" (iron, zinc, vitamin deficiencies) even when caloric intake is adequate. Conversely, healthy soils with active microbial communities facilitate nutrient cycling and plant uptake, improving food quality. Agricultural education that integrates soil health with nutrition outcomes would prepare students to address both productivity and public health simultaneously.

5.3 Comparison with International Findings

The findings of Kumru Akın and Palabıçak (2026) are consistent with international research. Durán Gabela et al. (2022), studying agricultural students in Ecuador, reported that 71.9% had high attitude toward sustainable agriculture but only 62.1% had high knowledge—a similar knowledge-attitude gap. In the United States, agricultural students demonstrate moderate sustainability knowledge with significant variation by specialization (as cited in Kumru Akın & Palabıçak, 2026). The consistency of these findings across geographical contexts suggests systemic issues in agricultural education worldwide.

5.4 Limitations of the Synthesis

This synthesis inherits limitations from the source documents. The student assessment was conducted at a single university (Harran University) with 145 participants, limiting generalizability. The SAKL survey, while showing high internal consistency (Cronbach's $\alpha = 0.95$), has not undergone extensive construct validation across multiple institutions. The soil health management review by Choudhary and Choudhary (2026) is practice-oriented rather than systematic, potentially omitting some evidence bases. Furthermore, neither source directly measured practical competencies (e.g., ability to interpret a soil test report or formulate a compost mixture); both relied on self-reported knowledge. Future research should incorporate performance-based assessments.

6. Recommendations for Curriculum Integration

Based on the synthesis of soil health management strategies and student knowledge assessment findings, the following curriculum integration recommendations are proposed.

6.1 Strengthen Soil Biology and Organic Matter Content

Given the lowest SAKL score for compost/biofertilizer knowledge (2.91 ± 1.20), curricula should explicitly and repeatedly address soil biological management. Specific actions include:

- Dedicated module on composting science and practice, including hands-on compost pile construction and monitoring
- Laboratory exercises isolating and identifying beneficial soil microorganisms (Rhizobium, PSB, mycorrhizae)
- Field demonstrations comparing crop growth with and without biofertilizer applications
- Case studies of successful organic matter rehabilitation in semi-arid environments

6.2 Integrate Soil Testing Interpretation Across Departments

Soil testing is the "foundational diagnostic tool" (Choudhary & Choudhary, 2026), yet student knowledge of soil health maintenance methods is only moderate (2.99 ± 0.99). Curriculum interventions should include:

- Required laboratory course on soil sampling, laboratory analysis, and report interpretation
- Integration of soil test data into crop management, pest management, and agricultural economics courses
- Simulation exercises where students make fertilizer and amendment recommendations based on real soil test reports
- Competency assessment requiring students to explain soil pH, EC, and nutrient data to a mock farmer

6.3 Implement Interdisciplinary INM Training

Integrated Nutrient Management requires understanding both synthetic and organic inputs. The moderate score on fertilizer effects (3.13 ± 1.13) suggests fragmented knowledge. Recommended approaches:

- Team-taught module involving agronomists, soil scientists, and agricultural economists
- Partial budget analysis comparing INM with conventional and organic-only approaches
- Long-term field trial visits (where available) demonstrating INM effects over multiple seasons
- Crop-specific INM recommendations for major regional crops

6.4 Address Departmental Disparities

The significant departmental differences ($p = 0.01$) indicate that sustainability knowledge is not uniformly distributed. Institutions should:

- Audit course syllabi across departments to identify sustainability content coverage
- Establish minimum sustainability competencies for all agricultural graduates regardless of specialization
- Create interdisciplinary sustainability courses accessible to all departments

Provide faculty development on integrating soil health principles into non-soil courses (e.g., agricultural economics courses covering the cost-benefit of organic amendments)

6.5 Connect Soil Health to Sustainable Nutrition Behaviors

The positive correlation ($r = 0.44$) between sustainable agriculture knowledge and sustainable nutrition behaviors suggests synergistic curriculum opportunities:

Modules on soil health–crop nutrient density–human health linkages

Cafeteria interventions offering soil-healthy food choices (e.g., compost-grown vegetables)

Student projects analyzing the carbon and water footprint of different dietary patterns

Joint assignments between agriculture and nutrition/dietetics programs where these exist

6.6 Enhance Practical Training and Experiential Learning

Knowledge retention and competency development require active learning. Recommendations include:

Mandatory internship or field project with soil health monitoring component

University farm demonstrations of cover cropping, green manuring, and composting systems

Biofertilizer production laboratory where students culture and formulate microbial inoculants

Citizen science projects where students assist local farmers with soil testing and interpretation

7. Proposed Framework: Soil Health Competencies for Agricultural Graduates

Drawing from the synthesis, Table 1 presents a competency framework for soil health education, organized by the five strategic domains from Choudhary and Choudhary (2026), aligned with the knowledge gaps identified by Kumru Akın and Palabıçak (2026).

Table 1. Soil Health Competency Framework for Agricultural Curricula

Strategic Domain	Core Competency	Current Student Knowledge Status	Recommended Curriculum Intervention
Soil Testing	Interpret soil test reports (pH, EC, N, P, K, micronutrients) and translate into amendment recommendations	Moderate (2.99 ± 0.99 for soil health methods)	Required lab course with authentic soil test interpretation exercises
Organic Matter	Explain functions of organic matter in water retention, nutrient supply, and soil structure; demonstrate composting techniques	Low (2.91 ± 1.20 for compost/biofertilizer contribution)	Hands-on compost production; field demonstrations of organic matter effects
Integrated Nutrient Management	Design INM plans combining synthetic fertilizers with organic amendments for specific crops and soil conditions	Moderate (3.13 ± 1.13 for fertilizer effects)	Team-taught module; partial budget analysis; case studies
Biofertilizers & Microbial Solutions	Identify beneficial microorganisms (Rhizobium, PSB, mycorrhizae); formulate and apply biofertilizers	Low (2.91 ± 1.20 shared with compost item)	Microbiology lab; biofertilizer production; field efficacy trials
Land Remediation	Diagnose salinity, alkalinity, and hardpan problems; prescribe amendments (gypsum) and cover crops (Sesbania)	Not directly assessed (covered under soil health methods)	Field visits to degraded and restored sites; remediation planning projects

8. Conclusion

This synthesis paper has integrated two complementary bodies of work: evidence-based soil health management strategies for sustainable agriculture, and an empirical assessment of agricultural students' knowledge of sustainable agriculture and nutrition. The integration reveals a critical gap: while soil health science increasingly emphasizes the importance of organic matter, biofertilizers, integrated nutrient management, and soil biological processes, agricultural students demonstrate their lowest knowledge levels precisely in these domains. The lowest-scoring item in the student assessment—awareness of compost and biofertilizer contributions to sustainable agriculture—corresponds directly to what Choudhary and Choudhary (2026) call the "beating heart" of soil fertility.

This gap has practical consequences. Future agricultural professionals who lack soil health competencies will be ill-equipped to address the converging challenges of climate change, land degradation, and food security. They may default to conventional high-input systems that degrade soil further, or they may embrace superficially "sustainable" practices without understanding the biological foundations that determine long-term outcomes.

The good news from this synthesis is that agricultural education does increase sustainable agriculture knowledge over time. Fourth-year students significantly outperform first-year students. This indicates that curricula are having some positive impact. However, the persistence of specific gaps—particularly in soil biology and organic matter management—suggests that current curricula are not adequately covering these topics or are covering them in ways that do not lead to durable knowledge.

The integrated framework proposed in this paper offers a roadmap for curriculum reform: strengthen soil biology content, integrate soil testing interpretation across departments, implement interdisciplinary INM training, address departmental disparities, connect soil health to nutrition, and enhance experiential learning. These recommendations are actionable and grounded in both soil science and educational assessment data.

Ultimately, closing the knowledge-practice gap in soil health education is not merely an academic exercise. It is a prerequisite for preparing the next generation of agricultural professionals to steward the foundation of our food system. As Choudhary and Choudhary (2026) conclude, soil that is treated as inert dirt exhausts; soil that is managed as a living ecosystem regenerates. Agricultural education must ensure that every graduate understands this distinction and possesses the competencies to put soil health principles into practice.

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