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Mechanical Property Tests of Garlic Plants and Components (Axial Tension, Radial Compression, Shear) V.1

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Abstract

This protocol describes the methods for axial tension, radial compression, and shear tests on garlic plants, garlic scapes, and pseudo-stems. Key mechanical parameters such as elastic modulus and ultimate strength are obtained using a universal testing machine, providing data support for optimizing the scape-stem separation mechanism in mechanized garlic scape harvesting. Applicable to the field of crop mechanical property research, the samples are mature and intact garlic plants, and the test procedure strictly complies with the GB/T1040.5-2006 standard.

Attachments

DOCX

Supporting informati...

8.7MB

Image Attribution

Jing Yang,Xin Guo,Baogang Xian,Shengben Lin.

Guidelines

It is necessary to control the sample size properly and clearly distinguish the differences between garlic sprouts, false stems and the main plant body.

Materials

List of Materials Required for Mechanical Property Tests of Garlic Plants and Components

(Classified as "Test Materials - Core Equipment - Measuring Tools - Data Processing Tools - Experimental Consumables", all derived from the experimental design in the document, suitable for axial tension, radial compression, and shear tests directly)

I. Test Materials

- White garlic plants: Mature, intact and unbroken, harvested from Sanyangchuan Garlic Planting Base, Tianshui City, Gansu Province, China (May 2025 harvest), stored in sealed and refrigerated conditions to prevent moisture loss.

II. Core Experimental Equipment

- Universal Testing Machine: Manufactured by Wance Company (Shenzhen, China), with a capacity of 10000N and accuracy of 0.18%, equipped with special fixtures for tension, compression, and shear tests.
- Scaled-down clamping wheels: Thickness 10mm, diameter 50mm, used to simulate clamping scenarios in radial compression tests.
- Single-sided blade: Used as the loading component for shear tests, installed on the upper chuck of the universal testing machine.

III. Measuring Tools

- Vernier caliper: Accuracy 0.01mm, used to measure plant diameter (80-100mm above the ground), garlic scape diameter (root, middle, and upper sections separately), and pseudo-stem thickness/width.
- Electronic scale: Used to weigh the mass of garlic scape and pseudo-stem, assisting in calculating the volume ratio.
- 105°C oven: Used to measure the moisture content of fresh plants by the drying method.
- Drainage device: Used to measure the density of garlic scape and pseudo-stem by the drainage method.

IV. Data Processing Tools

- Software: Microsoft Excel 2020 (for raw data recording), Origin 2024 (for statistical analysis and graph plotting).

V. Experimental Consumables

- Sealed plastic bags: Used for refrigerated storage of samples after harvesting to avoid moisture loss.
- Gauze: Wrapped around the clamped parts of samples to prevent slipping during tension tests.
- Disposable gloves: Used for sample handling to avoid contamination or hand injury.

- Laboratory notebook: Used for manually recording key parameters and abnormal conditions during tests.
- Cutting tools: Used to prepare samples of specified sizes (e.g., 350-500mm tensile samples of garlic scape, 20mm compression samples, etc.).

1.Experimental Materials and Reagents

1 Experimental Materials and Reagents

1.1 Sample Preparation
Sample source: Sanyangchuan Garlic Planting Base, Tianshui City, Gansu Province, China (collected in May 2025)

Sample type: White garlic variety, mature and intact garlic plants without damage

Pretreatment: Samples are sealed in plastic bags and stored in a refrigerator to prevent moisture loss, and returned to room temperature before testing

Sample parameter measurement: Measure the following parameters with a vernier caliper (accuracy 0.01mm) for each sample (8 measurements per parameter to obtain the average value)

Garlic plant: Diameter at 80-100mm above the ground

Garlic scape: Diameters of root, middle, and upper sections; cut samples of 20mm (compression test), 50mm (shear test), and 350-500mm (tension test) in length

Pseudo-stem: Thickness and maximum width; processed into rectangular samples of 100mm (tension), 50mm×20mm (compression), and 30mm×30-40mm (shear)

Moisture content determination: Measured by the 105°C drying method, the moisture content of fresh garlic scapes is 85.88±2.41%

Density determination: Measured by the drainage method, the density of garlic scapes is 970 kg/m^3, and the density of pseudo-stems is 620 kg/m^3

Garlic sprouts plants

Garlic sprouts plants

Garlic sprouts plants

young garlic shoot

1.2 1.2 Reagents (No special chemical reagents, only experimental auxiliary materials)

Gauze (used to wrap the clamped end of samples to prevent slipping during testing)

Deionized water (used for density measurement by the drainage method)

density measurement

density measurement

2.Experimental Equipment

2

- Universal Testing Machine: Specification is 10000 N capacity with 0.18% accuracy; Manufacturer is Wance Company, Shenzhen; Purpose is for axial tension, radial compression, and shear tests.
- Vernier Caliper: Specification is 0.01 mm accuracy; Manufacturer is not specified; Purpose is for sample dimension measurement.
- Electronic Balance: Specification is 0.001 g accuracy; Manufacturer is not specified; Purpose is for sample mass weighing.
- Oven: Specification is temperature-controllable at 105°C; Manufacturer is not specified; Purpose is for moisture content determination.
- Drainage Density Kit: Specification includes beaker, graduated cylinder, and electronic scale; Manufacturer is not specified; Purpose is for density measurement.
- Custom Clamping Fixture: Specification is clamping wheels with 10 mm thickness and 50 mm diameter; Manufacturer is self-made; Purpose is for radial compression test.
- Single-Sided Blade: Specification is not specified; Manufacturer is not specified; Purpose is for shear test.

- Gauze: Specification is not specified; Manufacturer is not specified; Purpose is to prevent sample slipping during clamping.

3.Experimental Procedures

3 Experimental Procedures

3.1 Sample Pretreatment

1. Remove refrigerated garlic plants from sealed bags and equilibrate at room temperature for 30 min.
2. Process samples into specified dimensions (Section 1.1) to ensure uniformity and no damage.
3. Wrap the clamped ends of tension/shear samples with gauze to avoid slipping or damage.
4. Record key dimensions (diameter/thickness/width/length) for cross-sectional area calculation (A: circular = $\pi d^2/4$; rectangular = bh).

3.2 Axial Tension Test (Garlic Scape and Pseudo-Stem Only)

1. Install custom clamping wheels (upper movable, lower fixed) on the testing machine; set loading speed = 5 mm/min.
2. Plant: Fix garlic plants between wheels, clamping at 80–100 mm above ground (consistent with manual harvesting).
3. Garlic Scape: Place 20 mm axial segments horizontally between wheels for uniform force application.
4. Pseudo-Stem: Place 50 mm×20 mm rectangular samples along the vein direction between wheels.
5. Start the test; record stress-strain curves until compression damage (stress peaks and declines).
6. Repeat n=8 times per sample type; save data.

Axial Tension Test

3.3 Radial Compression Test (Plant, Garlic Scape, Pseudo-Stem)

1. Install custom clamping wheels (upper movable, lower fixed) on the testing machine; set loading speed = 5 mm/min.
2. Plant: Fix garlic plants between wheels, clamping at 80–100 mm above ground (consistent with manual harvesting).
3. Garlic Scape: Place 20 mm axial segments horizontally between wheels for uniform force application.
4. Pseudo-Stem: Place 50 mm×20 mm rectangular samples along the vein direction between wheels.
5. Start the test; record stress-strain curves until compression damage (stress peaks and declines).
6. Repeat n=8 times per sample type; save data.

Radial Compression Test

Radial Compression Test

3.4 Shear Test

1. Mount a single-sided blade on the upper fixture (lower fixture = flat support); set loading speed = 5 mm/min.
2. Plant: Cut 100 mm segments 50 mm above the root; fix between fixtures, align blade with the central axis.
3. Garlic Scape: Cut 50 mm middle segments; fix horizontally, blade perpendicular to the scape axis.
4. Pseudo-Stem: Fix 30 mm×30–40 mm rectangular samples; shear perpendicular to veins.
5. Start the test; record stress-strain curves until complete fracture.
6. Repeat n=8 times per sample type; save raw data.

Shear Test

Shear Test

Shear Test

Shear Test

Shear Test

4.Data ProcessingUntitled section

4 Data Processing

1. Record raw data (force, displacement, dimensions) using Microsoft Excel 2020.
2. Calculate stress (σ = F/A) and strain; plot stress-strain curves with Origin 2024.
3. Determine elastic modulus via secant modulus method (slope of the line connecting the origin to 50% ultimate stress).
4. Calculate average values and standard deviations for all parameters (n=8).
5. Verify data using composite material mechanics formulas:
6. Radial compression: Ex = ExjVj + ExtVt (Equation 5)
7. Shear: Gyz = (Gyzj×Gyzt)/(VjGyzj + VtGyzt) (Equation 6)

5.Key Results and Validation

5 Key Results and Validation

5.1 Critical Mechanical Parameters

- Garlic Scape: Axial Tensile Elastic Modulus is 17.08±2.67 MPa; Radial Compressive Elastic Modulus is 5.78±2.23 MPa; Shear Modulus is 1.53±0.26 MPa; Ultimate Strength includes Tensile: 0.98±0.17 MPa, Compressive: 1.97±0.77 MPa, and Shear: 0.80±0.20 MPa.
- Pseudo-Stem: Axial Tensile Elastic Modulus is 57.03±12.16 MPa; Radial Compressive Elastic Modulus is 1.71±0.78 MPa; Shear Modulus is 5.21±1.50 MPa; Ultimate Strength includes Tensile: 2.04±0.56 MPa, Compressive: 4.02±2.14 MPa, and Shear: 12.48±6.02 MPa.
- Garlic Plant: Axial Tensile Elastic Modulus is 45.62 MPa (calculated); Radial Compressive Elastic Modulus is 2.85±0.54 MPa; Shear Modulus is 1.45±0.23 MPa; Ultimate Strength includes Compressive: 2.51±0.31 MPa and Shear: 0.87±0.34 MPa.

6.Validation

6 **Radial Compression**: Theoretical Ex (2.87 MPa) vs. measured Ex (2.85 MPa); relative error = 0.7% (consistent within 95% confidence interval).
Shear: Theoretical Gyz (1.92 MPa) > measured Gyz (1.45 MPa); relative error = 25.5% (caused by adhesion slip between scape and pseudo-stem).

7.Note

7 **Radial Compression**: Theoretical Ex (2.87 MPa) vs. measured Ex (2.85 MPa); relative error = 0.7% (consistent within 95% confidence interval).
Shear: Theoretical Gyz (1.92 MPa) > measured Gyz (1.45 MPa); relative error = 25.5% (caused by adhesion slip between scape and pseudo-stem).

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