



Science
Societies

Improving hemp yield and fiber quality through regenerative organic systems

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Fiber hemp is shown on the left and grain hemp on the right during the growing season in the field.

Industrial hemp is re-emerging as a valuable crop for fiber, textiles, bio-composites, and other renewable products. From 2021 to 2024, researchers in Pennsylvania examined how tillage, cover crops, and nitrogen management influence hemp performance in regenerative organic systems. The findings offer valuable insights for growers seeking to balance yield, fiber quality, and conservation-minded practices.

Industrial hemp is re-emerging as a valuable crop for fiber, textiles, bio-composites, and other renewable products. As more farmers explore hemp production, there is a growing need for practical, science-based guidance on how to manage the crop for strong yields, high quality fiber, and long-term soil health. The challenge is designing systems that support productivity while remaining environmentally responsible and economically viable.

From 2021 to 2024, researchers at the Rodale Institute in Kutztown, PA examined how tillage, cover crops, and nitrogen (N) management influence hemp performance in regenerative organic systems. The work was published recently in [Agronomy Journal](#) and [Industrial Crops and Products](#). The findings offer valuable insights for growers seeking to balance yield, fiber quality, and conservation-minded practices.

A key part of this research was evaluating hemp within a legume–hemp–barley rotation. Rotations that include legumes and small grains can improve N cycling,

reduce weed pressure, diversify rooting depth, and strengthen soil structure. Legumes supply biologically fixed N, hemp provides strong mid-season weed suppression and deep rooting, and barley captures residual nutrients while adding rotational diversity. Together, this system supports soil health while reducing reliance on external inputs, an important goal in organic and regenerative farming.

Yield benefits from tillage and cover crops

The study compared conventional tillage and no-till systems, with and without legume cover crops, across four N rates (0, 45, 90, and 135 lb N/ac via blood meal).

Researchers evaluated biomass production, plant N uptake, fiber strength, and soil health properties.

When total biomass was the primary focus, tilled systems with cover crops performed best. The highest biomass yield (4.1 tons/ac) occurred under tillage with cover crops and the highest N rate. Nitrogen application stimulated plant growth, increasing leaf N concentration from 2.8% without fertilizer to 3.2% at 135 lb N/ac.

These results show that tillage combined with cover crops can improve nutrient availability and plant uptake, leading to greater aboveground growth. In the rotation system, legume cover crops contributed additional N, helping to support hemp growth and reducing dependence on purchased fertilizers. For growers aiming to maximize biomass, moderate to higher N rates under tilled



Cover crop termination ahead of main crop planting.

systems may increase overall production. Barley grown after hemp responded positively to prior cover cropping and N management, suggesting that improvements in nutrient cycling carried forward into the following crop. This reinforces the value of rotational planning in hemp-based systems.

Stronger fiber from regenerative systems

While higher N supported biomass production, it did not enhance fiber strength. The strongest fibers were produced under no-till systems with cover crops and no added N.

Under this regenerative combination:

- Tenacity (strength of single fiber) reached 610.5 MPa.
- Work of rupture (total energy to break) reached 4554 psi.
- Maximum load (maximum force a fiber can withstand before breaking) reached 5.4 lb.

In contrast, increasing N, particularly from 45 to 90 lb N/ac, often reduced fiber strength under tilled conditions. These findings reveal a clear trade-off. Greater N inputs may increase vegetative growth, but excessive fertility can weaken structural fiber properties. Systems that integrate cover crops and reduce soil disturbance supported stronger, more resilient fiber.

The legume–hemp–barley rotation strengthens the system by improving nutrient cycling and soil function. Legumes gradually supply biologically fixed N, hemp's deep roots enhance soil structure and access deeper nutrients, and barley efficiently captures remaining nutrients while maintaining ground cover. This rotation supports steady nutrient cycling rather than rapid nutrient flushes, which may help explain why lower-input systems produce stronger fiber. For markets that demand high tensile

strength and durability, such as textiles, low-input regenerative systems may offer distinct advantages.



Left: Harvested fiber hemp laid on ground for drying and retting. **Right:** Dried hemp stalks stacked after harvest.

Practical implications for farmers and their advisers

Management decisions should reflect production goals. Growers seeking maximum biomass may benefit from tilled systems with cover crops and moderate N inputs. Those targeting premium fiber quality may find greater value in no-till systems with cover crops and reduced fertilizer use.

The study also shows that N can be optimized rather than maximized. Moderate or low fertilizer rates, when paired with soil-building practices and diversified rotations, can sustain crop performance while improving fiber quality.

As hemp production continues to expand, regionally based research like this helps farmers and their advisers make informed choices. The results demonstrate that thoughtful nutrient management, diversified rotations, and soil-supportive practices can work together to produce hemp that is productive, high quality, and sustainably grown for the long term.

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Dhakal, M., Panday, D., Etemadi, F., Afshar, R. K., Lapham, C., Smith, A., & Ghalehgoiabbehbahani, A. (2026). Tillage and cover cropping enhanced yield, nitrogen use efficiency, and soil health in organic industrial hemp–barley rotations. *Agronomy Journal*, 118(1), e70306. <https://doi.org/10.1002/agj2.70306>

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