



Technical Analysis of Planter Technologies at AGRITECHNICA 2025: Observations, Trends, and Scientific Assessments

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ABSTRACT

This study provides a detailed examination of the latest technological developments in planters presented at AGRITECHNICA 2025, held in Hannover, Germany, between 09-15 November 2025. Throughout the exhibition, the planter technologies exhibited by leading global agricultural machinery manufacturers were systematically examined, with particular emphasis placed on precision seeding technologies, including electro-mechanical control systems, sensor integration, high-speed seeding mechanisms, seed metering units, furrow opener designs, and solutions supporting regenerative agriculture practices. The observations reveal that technological advancements in industry are predominantly concentrated on precision planters, whereas innovations addressing grain drill seeding systems and regenerative agriculture applications—such as intercropping, multi-variety sowing, and cover cropping—remain notably limited. This article discusses the academic and industrial implications of these findings and identifies future research priorities within the field of seeding technology.

Keywords: Precision seeding, Innovation, Seeding machines, Current trends.

INTRODUCTION

The transition toward sustainable agricultural production systems and the increasing demand for higher efficiency have made rapid advancements in modern seeding technologies essential. Precision agriculture practices enable the management of within field variability, allowing more efficient use of inputs while reducing environmental impacts. In this context, innovative approaches such as variable rate seeding, intercropping, and no-tillage seeding not only optimize crop



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development but also support soil-conserving and environmentally sustainable farming practices.

Recent scientific studies on seeding technologies have primarily focused on the performance evaluation of individual planter components, including seed metering systems, furrow openers, high-speed planting units, and electronic control systems under experimental or field conditions. Although these studies provide valuable engineering insights, the literature still lacks comprehensive and critically evaluated reviews that systematically examine the current industrial direction of planter technologies presented at international agricultural machinery exhibitions. In particular, there is limited scientific documentation regarding how emerging commercial planter technologies align with ongoing academic research priorities, sustainability goals, and regenerative agriculture requirements. Consequently, a significant gap exists between rapidly evolving industrial innovations and their scientific assessment within the literature.

AGRITECHNICA, one of the world's most comprehensive international exhibitions for agricultural technology, serves as a major platform where innovations in agricultural machinery are showcased, compared, and critically evaluated. In this study, technological developments in planters exhibited at the fair were examined in detail.

The seeding solutions presented by leading international agricultural machinery manufacturers from Europe, North America, and South America were observed and comparatively evaluated in terms of their technical characteristics, including precision seeding systems, electro-mechanical control technologies, furrow opener designs, and high-speed planting mechanisms. The assessment included technologies exhibited by major global planter manufacturers such as Horsch, John Deere, Väderstad, Lemken, Maschio Gaspardo, and several other manufacturers representing different technological approaches and regional markets.

Global Significance and Technological Ecosystem of the AGRITECHNICA Exhibition: First launched in 1985, the AGRITECHNICA exhibition has played a significant role in shaping the global development of agricultural machinery and technologies. The 2025 edition reaffirmed its status as the world's leading agricultural technology summit, hosting 2.849 exhibitors from 52 countries and welcoming 476.000 visitors from 171 nations.

The exhibition serves as a central hub for R&D activities in agricultural machinery. While major manufacturers from Europe and North America were strongly represented, participation from South America and Asia was more limited. Notably, the relatively low presence of manufacturers from rapidly advancing East Asian countries - such as China - affected the global diversity and geographical balance of the fair. In the specific context of seeding technologies, the dominance of European manufacturers raised concerns regarding the limited intercontinental diversity within this product group.

Unlike conventional exhibition reports that are predominantly descriptive, the present study aims to provide a scientific and critical interpretation of planter technologies by linking observed industrial trends with existing academic knowledge and future research demands. The study therefore contributes to the literature by: (i) systematically classifying contemporary planter technologies exhibited at

AGRITECHNICA 2025; (ii) identifying technological trends and innovation priorities within the global seeding machinery industry; (iii) critically evaluating the extent to which current commercial developments address sustainability and regenerative agriculture objectives; and (iv) revealing technological deficiencies and underrepresented research areas, particularly regarding grain drills, cover crop seeding, intercropping systems, and multi-variety sowing technologies. In this respect, the manuscript provides not only a technical review of exhibited machinery, but also a research-oriented assessment intended to guide future academic studies and industrial development in seeding technologies.

The primary aim of this study is to analyze the current state of sensor technologies and electro-mechanical systems used in planters, innovations in high-speed seeding mechanisms, advancements in furrow opener designs, and the overall suitability of contemporary seeding technologies for sustainable, conservation-oriented, and regenerative agriculture practices. Additionally, the study seeks to identify both the strengths of the technologies examined and the design or functional limitations that still require development within the industry.

SEEDING TECHNOLOGIES FOR CONSERVATION AND REGENERATIVE AGRICULTURE

Regenerative Agriculture (RA) is a holistic production philosophy aimed at improving soil health, enhancing biodiversity, and managing carbon cycles in accordance with natural ecological processes. Key strategies include no-tillage, intercropping, multi-variety seeding, and cover cropping—each contributing to the preservation of soil structure and the long-term functionality of agroecosystems.

The technologies examined at the exhibition indicated that most contemporary planters remain primarily designed for monoculture and single-variety seeding, with only limited adaptation for RA-oriented applications. Although no-tillage systems were widely supported (Figure 1), notable technological gaps existed in other RA components. In no-till planters, manufacturers primarily emphasized the use of star discs for clearing crop residues directly over the seeding row and wavy (ripple) discs designed to cut through soil and surface residues ahead of the furrow opener (Figure 2). These findings indicate that RA-oriented seeding technologies have yet to be addressed through a fully integrated engineering approach. Consequently, future developments are expected to move toward modular, adaptive, and sensor-assisted seeding systems capable of accommodating diverse soil environments and multi-species seeding scenarios.



Figure 1. Planter units designed for no-tillage.



Figure 2. Furrow opener and disc models developed for no-tillage planters.

Current Trends in Planter Technologies

Electric Drive System

In recent years, the adoption of electric motors as primary drive systems in planters has expanded rapidly. Across the examined manufacturers, planter models equipped with electrically driven metering units were widely identified, together with electronically or hydraulically controlled functions such as seeding depth adjustment, downforce regulation, and field/transport position transitions. These advancements significantly enhance compatibility with precision agriculture applications.

The exhibited planter systems predominantly utilized low-voltage DC electric motors, brushless DC (BLDC) motors, and servo-controlled electric drive units for individual row-unit seed metering systems. In particular, BLDC motors were widely preferred due to their high torque characteristics, rapid response capability, precise rotational speed control, compact structure, and reduced maintenance requirements. Servo-assisted electric drive systems additionally enabled row-by-row variable-rate seeding, section control, and improved synchronization between travel speed and seed delivery rate ([Ling et al., 2024](#); [Wang et al., 2026](#)).

In particular, systems operating in full integration with the ISOBUS standard reduce operator workload and facilitate data-driven farm management. Electric drive systems improve energy efficiency, lower noise levels, and offer superior control accuracy. As noted in the literature ([Bongiovanni and Lowenberg-DeBoer, 2004](#); [Ghaffarnezhad et al., 2024](#); [Guan et al., 2026](#)), these developments support the digital transformation of agriculture and contribute to the standardization of seeding quality.

Advances in Sensor Technologies

The integration of sensors into modern planters has become an industry-wide standard, forming a crucial component of contemporary precision agriculture systems. Advances in sensor technology increase both the accuracy and automation capabilities of seeding operations, enabling more efficient, traceable, and sustainable production processes. Sensors are commonly used for monitoring seed flow, assessing soil conditions, tracking machine performance, and conducting real time automatic adjustments.

Optical sensors-typically based on infrared (IR) light barrier technology-are widely used to detect seed flow and count individual seeds passing through the seeding unit. They allow:

- Detection of skips and doubles in precision planters,
- Automatic alerts in case of seed flow blockages,
- Monitoring of flow stability in high-speed seeding applications.

Ultrasonic sensors, operating through acoustic waves, are used for:

- Seed hopper level monitoring,
- Real-time furrow opener depth control,
- Seed flow verification,
- Measurement of micro-variations on the soil surface.

These sensors are durable and long lasting due to their non-contact measurement capability.

Capacitive sensors are utilized for:

- Detecting seed presence and density,
- Distinguishing between different seed types based on dielectric properties,
- Hopper fill level monitoring.

Inductive sensors, on the other hand, are used for the position tracking of mechanical components such as discs and frame elements.

Real-time soil sensing plays a critical role in variable-rate seeding strategies.

Commonly used soil sensors include:

- Soil moisture sensors,
- Soil temperature sensors,
- Electrical conductivity (EC) sensors.

With RTK-enabled GNSS sensors:

- Row accuracy can be improved to ± 2 cm,
- Variable-rate seeding maps can be generated,
- Automatic row guidance during turns becomes possible.

Modern planters equipped with sensor suites reduce operator workload and increase seeding accuracy. ISOBUS-compatible terminals provide real-time monitoring of planted area, seed distribution uniformity, seeding speed, depth, and machine diagnostics (Figure 3). Optical seed flow sensors are widely used by firms such as Horsch, Väderstad, John Deere, and Monosem, especially in high-speed models.

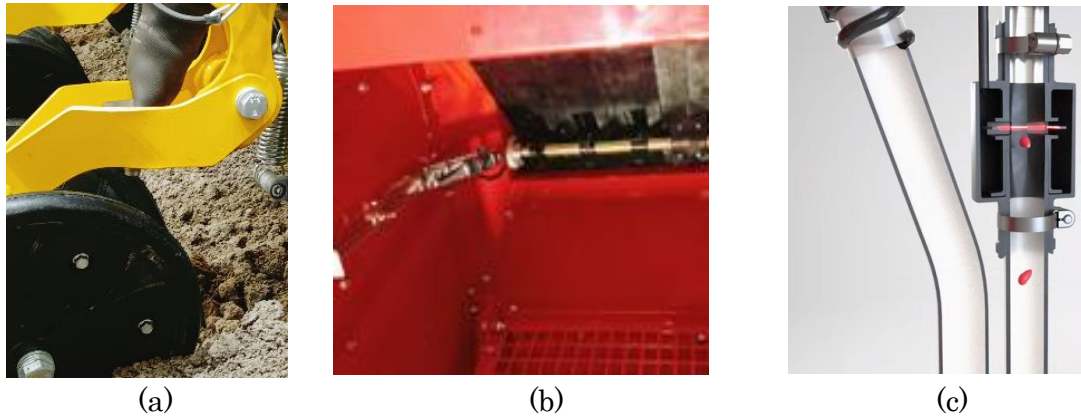


Figure 3. Sensor applications in planters. (a) Seeding depth sensor, (b) seed level sensor in the hopper, (c) seed tube flow sensor.

A notable example comes from Türkiye: Özdöken has developed a patented cross-seeding mechanism monitored by sensor systems, which places seeds in triangular spacing patterns. This design:

- Reduces root zone competition,
- Improves water and nutrient efficiency,
- Ensures more uniform crop development.

As discussed by [Altuntaş and Yılmaz \(2024\)](#) and [Šarauskis et al. \(2022\)](#), this method shows strong potential within sustainable agriculture frameworks.

High-Speed Seeding Systems

Historically, precision planters have been limited to operating speeds of 7-10 km h⁻¹. This limitation originates from issues such as seed bounce, rolling, skipping and horizontal displacement upon soil impact. In conventional systems, seeds fall freely through the seed tube after leaving the metering disc; as travel speed increases, seed horizontal velocity increases as well, causing misplacement on the seed row. Additionally, row unit vibration and inconsistent downforce at high speeds negatively affect depth control and row uniformity.

Recent technological innovations have largely mitigated these problems, enabling operational speeds of 15-20 km h⁻¹. These next generation systems incorporate mechanisms that control seed motion throughout the drop path and at the moment of soil contact.

Elevator-Based Seed Tube Mechanisms (Figure 4a): Used by manufacturers such as Monosem and Case, this system transports the seed from the metering unit to the soil surface via a moving belt or brush mechanism. It:

- Eliminates free-fall,
- Reduces horizontal momentum at high speeds,
- Ensures low-impact and accurate seed placement.

This significantly minimizes bounce and rolling, improving within row spacing uniformity.

Pneumatic Seed Acceleration/Deceleration Systems (Figure 4b): Employed by firms such as Maschio Gaspardo and Amazone, these systems use controlled airflow inside the seed tube. They:

- Maintain constant seed velocity within the tube,

- Stabilize seed placement by counteracting forward motion at soil contact,
- Reduce turbulence and drift effects at high speeds.

Thus, even at 15-20 km h⁻¹, high seeding precision is maintained.

High-speed seeding technologies combine advanced mechanical designs with sensor-driven control units, enhancing seeding accuracy while providing significant operational advantages to farms in terms of time efficiency, reduced fuel consumption, and improved labor productivity. As noted by [Barr *et al.* \(2019\)](#) and [Wang *et al.* \(2024\)](#), the importance of these systems will continue to rise parallel to the global adoption of precision agriculture.

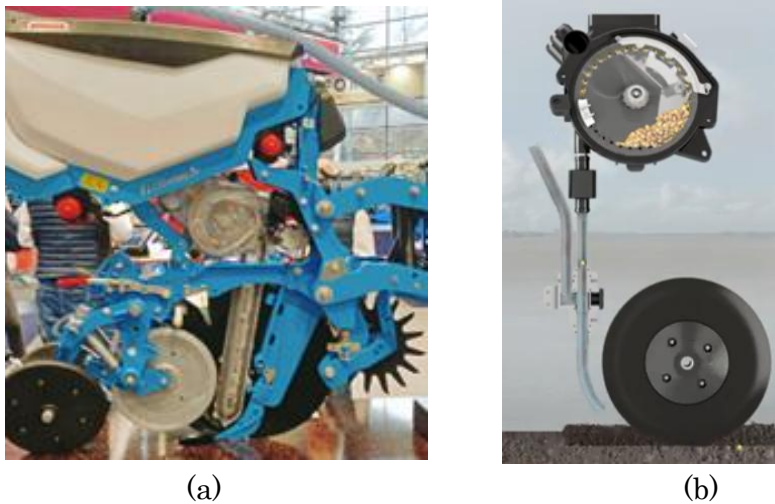


Figure 4. Seed tubes in high-speed planters: (a) Elevator-type seed tube, (b) air-assisted (pneumatic) seed tube.

Seed Metering Technologies

In precision planters, the seed metering unit is considered the most critical component, as it ensures the accurate and individual placement of seeds within the row. Since overall seeding quality largely depends on the precision of this mechanism, developments in metering technologies remain a prominent research and innovation focus in agricultural engineering. Currently, the dominant systems used in the industry include vacuum (negative-pressure) plate metering, positive-pressure pneumatic metering, and mechanical fluted roller or plate systems.

Vacuum-based plate metering systems are the most widely used technology in precision planters. Seeds are picked up by perforated plates through negative pressure. These systems are preferred due to their:

- Ability to handle multiple seed types with the same plate,
- Easy interchangeability of plates for varying seed sizes,
- High metering precision,
- Simple and mechanically robust structure,
- Minimal seed damage,
- Compatibility with high-speed seeding improvements.

Manufacturers such as Monosem, John Deere, Väderstad, and Kuhn have introduced innovations built upon this system, establishing it as the industry standard.

The Argentine manufacturer Bertini has developed a positive-pressure pneumatic metering system (Figure 4), which differs from traditional vacuum-based systems by directing seeds onto the plate through an outward air jet. This system aims to improve seed filling consistency by actively guiding the seeds into the perforations. Although positive-pressure systems are not yet widespread in the industry, Bertini's approach introduces a novel perspective to metering innovation due to its alternative operational principle.

In grain drill seeding equipment, mechanical fluted roller metering systems remain dominant. Although academic studies confirm that single seed precision seeding of grain drills is technically feasible ([Meng et al., 2019](#); [Xi et al., 2020](#); [Feng et al., 2024](#)), observations at the exhibition demonstrate that industrial adoption of precision metering technologies for grain drills is still in its early stages.

Furrow Opener Designs

Selecting furrow openers that match soil properties is essential for achieving correct seeding depth and consistent furrow geometry. Soil cutting resistance, moisture level, and surface residue all play critical roles in opener performance. Therefore, offering opener configurations that adapt to diverse soil conditions is vital for maintaining seeding quality.

The most observed opener types at the exhibition were disc, hoe, and chisel-type designs (Figure 5a). Disc openers provided better stability and residue handling performance in heavy or residue-rich soils, while hoe-type openers performed well in well prepared and loose soils due to their superior penetration capacity. Chisel openers, although advantageous for achieving greater seeding depths, may deposit seeds into excessively loose soil layers. This can lead to germination issues, particularly in arid regions where soil moisture is limiting.

Among the manufacturers, Väderstad stood out by offering a broad range of opener configurations suitable for different soil textures and tillage systems (Figure 5b). Their portfolio ranges from more aggressive star disc models for lighter soils to robust disc and chisel-type openers for heavy soils, enabling farmers to select equipment that matches varying field conditions.



(a)



(b)

Figure 5. Furrow opener types highlighted at the exhibition: (a) conventional opener designs, and (b) opener models developed by Väderstad.

Fertilizer Application Systems in Planters

Modern planters are commonly designed as combined machines, meaning they perform both seeding and fertilization in a single pass. With the increasing adoption of micro-granular fertilization in recent years, planters displayed at the exhibition were observed to incorporate not only conventional fertilizer applicators but also micro-granular delivery systems (Figure 6a). The integration of these units enables operators to apply standard granular (chemical) fertilizers and micro-granular fertilizers simultaneously, without requiring an additional implement, thus improving operational efficiency.

Some manufacturers, however, have chosen not to integrate micro-granular applicators directly into their planters. Instead, they offer portable micro-granular fertilizer systems, such as those produced by specialized companies like APV, as an alternative solution. These portable units can be mounted on a variety of seeding or tillage implements, providing flexibility for customers who may wish to use micro-granular fertilization across different machines rather than being limited to a single planter platform (Figure 6b).



(a)



(b)

Figure 6. Micro-granular fertilizer equipment integrated into planters (a), and portable micro-granular fertilizer application systems (b).

Machine Dimensions, Transport Systems, and Structural Design Trends

The development of wide working width planters has become a key trend, particularly for large-scale farming operations aiming to increase operational efficiency. As working width increases, the time required to seed a given area decrease, thus optimizing fuel consumption, labour requirements, and overall

operational costs. However, the portability of large machines presents significant challenges related to narrow rural roads, field entrances, and limited storage space. As a result, manufacturers frequently employ hydraulic folding mechanisms, multi-segment architectures, and modular chassis designs.

One of the most noteworthy innovations observed at the exhibition was introduced by the Argentine manufacturer Superwalter, which showcased a unique transport system allowing the entire planter frame to rotate around its longitudinal axis to achieve a lateral transport position (Figure 7). This rotating chassis mechanism:

- Dramatically reduces transport width,
 - Facilitates access to narrow fields,
 - Enables small and medium-sized farms to operate high-capacity planters,
- thereby representing a significant advancement in planter transport engineering.

Although large working widths increase operational efficiency, they also bring disadvantages such as higher machine weight, larger transport dimensions, and greater storage requirements, which can elevate operational costs. Therefore, consistent with the literature (Bochtis *et al.*, 2019), the industry is increasingly shifting toward lightweight materials, modular structures, and transport-efficient designs. Foldable, segmented, or axis rotating chassis solutions are expected to become standard features in future planter generations.



Figure 7. The transport system of the planter developed by Bertini (transport mode).

DISCUSSION

The technological trends observed at AGRITECHNICA 2025 indicate that the agricultural machinery industry is rapidly advancing along the axes of electrification, digital sensor integration, and automation. ISOBUS-compatible control units, high-speed seeding mechanisms, and sensor-driven adjustment systems collectively define the dominant direction of industry wide innovation. However, several critical technological gaps remain evident.

1. Lack of Equipment for Intercropping and Multi-Variety Seeding: Intercropping and multi-variety seeding are recognized within agricultural science as key strategies for enhancing soil health, improving biodiversity, and stabilizing yields. However, exhibition findings reveal that modular metering systems, multi-channel distribution mechanisms, and work units capable of simultaneous multi-depth or multi-row seeding are still underdeveloped in the commercial market.

One important reason for the limited presence of these technologies at international agricultural machinery exhibitions is that intercropping and multi-variety seeding systems are still relatively new and emerging application areas within modern mechanized agriculture. Compared with conventional monoculture-based planting systems, these technologies require more complex engineering solutions, including independent seed metering control, synchronized multi-channel seed delivery, and adaptable row unit configurations for different crop species and seed characteristics. In addition, since regenerative agriculture practices are still developing at different rates across countries and agricultural production systems, industrial demand for such specialized planter technologies remains comparatively limited. Consequently, many manufacturers continue to prioritize commercially established high-capacity monoculture planter systems, which currently dominate global agricultural markets and exhibition platforms.

The research project S-MIP-24-130 aims to address this gap by establishing the engineering foundations of dedicated intercropping-oriented seed distribution systems to support future industrial designs.

2. Insufficient Precision Metering Technologies for Grain Seeding: Mechanical fluted roller systems continue to dominate grain seed drills, which do not fully align with the uniform emergence requirements of modern production systems. Although the literature demonstrates the potential of pneumatic and electromechanical metering systems for high precision grain seeding, their industrial scalability remains limited. Developing metering units capable of single-seed precision for cereals represents a major future transformation area for the industry.

3. Need for Soil Specific Furrow Opener Designs: Exhibition observations show that many manufacturers continue to rely on standard opener configurations, with only a few companies (e.g., Väderstad) offering soil specific alternatives. In reality, the conditions such as surface crusting in arid regions, high penetration resistance in heavy soils, and erosion prone landscapes require optimized soil–tool interaction designs. This reveals a significant technological gap that must be addressed through both research and product development.

4. Strategic Importance of Academia–Industry Collaboration: Bridging these technological gaps requires closer collaboration between academic institutions and industry. Joint design processes, prototype testing, sensor integration, and data-driven optimization will play critical roles in accelerating technological progress. Considering the multidisciplinary engineering challenges posed by Regenerative Agriculture systems, strengthening university–industry partnerships is essential for the sector’s technological transition.

CONCLUSION

Technological Advancements in Contemporary Planters

The AGRITECHNICA 2025 exhibition demonstrates that planter technologies are undergoing a significant transformation driven by electro-mechanical systems, sensor-based control units, and high-speed seeding innovations. Depth control supported by optical and ultrasonic sensors, seed flow monitoring systems, and ISOBUS-based management interfaces have become industry standards, while

advanced seed delivery mechanisms introduced by manufacturers such as Monosem and Maschio Gaspardo have increased seeding speeds to 15–20 km/h, substantially enhancing operational capacity.

Technological Limitations and Research Gaps

However, the exhibition also revealed limited diversity in furrow opener designs and insufficient adaptability of seeding units to varying soil types—an area where only a few firms, such as Väderstad, offer a broad design portfolio. More critically, technologies required for Regenerative Agriculture, including intercropping, multi-variety seeding, and cover cropping, remain underdeveloped. Mechanical roller systems continue to dominate grain seeding equipment, despite evidence in the literature supporting the potential of pneumatic and electromechanical precision metering systems.

Future Research and Scientific Contribution

Overall, while the planter industry demonstrates strong progress in speed, automation, and electronic integration, substantial opportunities remain in mechanically adaptive designs, multi-species seeding architectures, and precision grain drill metering. Academic–industrial collaboration will be crucial in addressing these gaps. Engineering advancements in intercropping-compatible seeding systems, soil-adaptive furrow openers, and AI-assisted seeding control technologies represent key future directions. The findings of this study offer valuable insights into both industrial product development and future agricultural engineering research.

In this context, the project “Design, Development, and Evaluation of a Seeder Prototype for Intercropping and Multi-variety Sowing Systems at Variable Sowing Rates” (Project No: S-MIP-24-130) directly addresses several technological deficiencies identified in this study, particularly the limited availability of planter systems suitable for regenerative agriculture practices and multi-species seeding applications. The project contributes to the broader scientific context by supporting the development of adaptable and precision-oriented seeding technologies capable of improving sustainability, input efficiency, and operational flexibility in modern agricultural systems.

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DECLARATION OF COMPETING INTEREST

The authors unanimously declare that no conflict of interest exists in any manner.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Davut KARAYEL: Investigation, methodology, conceptualization, formal analysis, writing - original draft, review, and editing, visualization etc.

Eglė JOTAUTIENĖ: Investigation, methodology, conceptualization, formal analysis, writing - original draft, review, and editing, visualization etc.

ETHICS COMMITTEE DECISION

This article does not require any Ethical Committee Decision.

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