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A Comprehensive Review on Combined Agricultural Machinery for Multi-Crop Farming Systems

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Abstract

Mechanization has become indispensable for achieving efficiency, sustainability, and profitability in agriculture. Conventional farm implements typically perform single operations such as tillage, sowing, or basin formation, which necessitates multiple field passes, leading to higher fuel consumption, labor demand, soil compaction, and delayed operations. Combined agricultural machinery, which integrates two or more functions into a single pass, offers a practical solution to these challenges. This review synthesizes research advancements in basin formation machinery, sowing and planting devices, watercourse and furrow formers, and integrated combination implements developed for multi-crop farming systems. Studies consistently report that such machinery improves timeliness of operations, reduces operational costs by 30-50%, enhances field efficiency by 20–30%, and contributes to yield increases of 15–35% through better soil-water management and precise seed placement. Special attention is given to basin lister-cum-seeding devices, multi-crop seed drills, bund formers, sugarcane earthing-up cum fertilizer applicators, and automated basin listers, which demonstrate particular relevance for small and medium-scale farmers. While challenges remain in terms of high initial investment, adaptability to diverse soil conditions, and the requirement for skilled operation, the integration of lightweight modular designs with precision technologies such as GPS, IoT-based monitoring, and automated seed metering represents the future of combined agricultural machinery. The review concludes that widespread adoption of these innovations can play a transformative role in advancing sustainable and resource-efficient mechanization for multi-crop farming systems.

Key words : Combine machinery, sowing, light weight, multi crop, machinery .

Agriculture continues to play a pivotal role in India's economy, contributing nearly 18% to national Gross Value Added (GVA) and providing livelihoods to about 40% of the population (Government of India, 2023). Yet, the overall level of farm mechanization in the country is estimated at only 47%, much lower than in developed nations where it exceeds 90% (Singh et al., 2020). Small and marginal farmers, who constitute more than 85% of holdings, face additional constraints of fragmented land, low-horsepower tractors, and limited capital, which restrict the adoption of efficient mechanization (Mehta et al., 2014). Conventional farm operations rely on single-purpose implements, requiring multiple passes for ploughing, basin formation, sowing, and fertilizer application. This results in higher fuel and labor costs, greater soil compaction, and untimely sowing-an issue particularly critical in rainfed areas that account for 51% of India's net sown area and contribute about 40% of total food grain production (ICAR, 2019). Delays in operations here directly reduce yield potential.

To overcome these challenges, combined agricultural machinery has been developed to integrate two or more functions-such as tillage, basin formation, sowing, and fertilizer application-into a single pass. Studies in Indian conditions demonstrate that such machinery can improve field efficiency by 20-30%, reduce operational costs by Rs. 1200-3000 per hectare, and increase yields by 15-35% through better resource utilization (Kadam, 2020; Naik, 2023; Verma and Gupta, 2016). Among these,

basin formation machinery has gained special importance, as it not only ensures effective soil and water conservation but also provides the foundation for integrated sowing and planting operations.

Basin Formation and Integrated Implements : Basin formation is an essential soil and water conservation practice in dryland farming, especially in Vertisols, where problems of both waterlogging and moisture stress are common. Traditionally, basin making is done manually, requiring considerable labor and time. The development of combined basin lister-cum-seeding implements has enabled simultaneous basin formation and sowing, improving resource efficiency and timeliness.

Muthamiselvan *et* al. (2004) reported the development and evaluation of a tractor-mounted basin lister-cum-seeder designed to perform multiple operations in a single pass. The implement consisted of paired lister bottoms for basin formation, mounted on a tractor-drawn frame, along with a seed metering unit that enabled simultaneous soil opening, basin making, and seed sowing. Field trials demonstrated that the machine ensured uniform basin profiles, reduced the number of field operations, and enhanced the timeliness of sowing compared to conventional separate operations. Additionally, the integrated design minimized soil erosion and improved water conservation in basin areas, making it highly suitable for dryland farming conditions.

Kadam (2020) conducted a study on the Performance evaluation of a tractor-mounted basin lister for Vertisols. Constructed from mild steel with adjustable lister bottoms, the implement was suitable for 35 hp tractors. Field results showed a field efficiency of 69.47% and cost savings of Rs. 1383 ha^{-1} compared to separate operations, in addition to better in-situ soil moisture conservation.

Solanki *et* al. (2016) developed a bund former-cum-packer, which combined bund formation with compaction in a single operation. The implement consisted of bund-forming blades mounted on a tractor frame and a roller attachment for packing. It achieved a field capacity of 1.4 ha h^{-1} and produced uniform bunds that improved water retention in irrigated fields.

Turbatmath *et* al. (2016) designed a tractor-operated tie ridger for in-situ soil and water conservation. The equipment comprised ridge-forming blades arranged across the toolbar, which produced tie ridges perpendicular to the slope. Testing demonstrated a field efficiency of 75.9% and significant reductions in runoff and soil erosion, especially under rainfed conditions.

Kove *et* al. (2022) introduced an Arduino-based automated basin lister. The system used electronic sensors to control basin length, adjustable between 2.7 and 10.4 m. Evaluation reported 78.76% efficiency and operational flexibility superior to conventional listers. Such automation demonstrates the scope of integrating digital technology with traditional basin formation machinery.

These studies collectively highlight the progression from manual basin formation to integrated basin lister-cum-seeding systems and automated designs, demonstrating their importance for multi-crop farming under water-limited conditions.

Seeding and Planting Implements with Multi-Functional Attachments : Sowing is a critical stage in crop establishment, and the efficiency of this operation strongly influences plant stand, resource use, and yield. Conventional seed drills and planters often perform only a single function, requiring additional passes for tillage or fertilizer application. Recent advances have emphasized multi-functional seeding machinery that

combines sowing with other operations such as tillage, fertilizer placement, herbicide application, and watercourse formation.

Manian et al. (2003) reported the development and evaluation of a tractor-mounted till planter that integrated tillage, ridge formation, and planting operations in a single pass. The implement was equipped with ridger bottoms for soil manipulation and a seed metering system mounted on a toolbar frame to ensure precise seed placement. Performance evaluations indicated a field capacity of 0.81 $ha \bullet h^{-1}$, representing a substantial reduction in operational time and fuel consumption when compared with conventional separate tillage and sowing practices. The implement also facilitated uniform ridge formation, thereby enhancing crop establishment.

Manian et al. (2008) developed a tractor-operated basin lister-cum-seeder designed to perform basin formation in conjunction with simultaneous seed placement. The machine was tested under dryland farming conditions and demonstrated notable improvements in seed placement accuracy and soil moisture conservation. Field evaluations revealed higher germination percentages and more uniform crop stands relative to traditional methods, underscoring its suitability for rainfed agricultural systems.

Wang et al. (2008) designed a powered disc no-tillage planter specifically tailored for ridge-tillage systems. The implement incorporated disc-based residue management mechanisms that enabled simultaneous sowing and ridge formation, thereby reducing the number of field operations. Field evaluations demonstrated improved operational efficiency under conservation agriculture conditions, with better residue handling and soil disturbance minimized compared to conventional planting methods. The study highlighted the potential of such integrated machinery to enhance productivity and sustainability in ridge-based cropping systems.

Singh and Vatsa (2007) designed a manually operated seed drill specifically for hill agriculture, fabricated from lightweight materials to facilitate ease of handling in terraced fields. The implement incorporated adjustable seed metering plates, enabling adaptability for a range of crops. Comparative studies with broadcasting showed a reduction in labor requirements by 78% and sowing costs by 62%, while achieving improved uniformity in seed distribution and enhanced plant population in hilly terrains.

Verma and Gupta (2016) reported on a multi-crop seed-cum-fertilizer drill suitable for maize, wheat, and pulses. The implement incorporated fluted roller seed meters and a fertilizer box, allowing simultaneous seed and fertilizer placement. Evaluation indicated high placement accuracy, reduced seed damage, and operational efficiencies superior to traditional seed drills.

TNAU (2016) reported the development of a tractor-mounted basin lister–cum-seeder requiring 35 hp for operation. The implement was designed to perform basin formation and seed placement simultaneously, thereby reducing the number of field operations. Field evaluations demonstrated a 10% improvement in soil moisture retention, along with higher crop yields compared to conventional methods. Moreover, the machine achieved substantial savings in terms of cost (32%), time (96%), and energy consumption (18%), underscoring its effectiveness and economic viability for basin-based farming systems.

Samreen et al. (2017) developed a roto drill-cum-herbicide applicator that integrated sowing, fertilizer application, and chemical weed control within a single operation. The implement was designed with a rotary tillage system coupled to seed and fertilizer metering devices, along with

a calibrated herbicide applicator for precise chemical delivery. Performance evaluations indicated a 26% reduction in operational time compared with conventional separate operations, without compromising the efficiency of weed management. The study demonstrated that such combined machinery not only enhanced field efficiency but also reduced labor requirements and overall cultivation costs.

Li et al. (2018) designed a no-till planter that combined residue cutting, fertilizer placement, and seed sowing into one operation for high-residue conservation agriculture in China. The machine used disc-type residue cutters to handle surface-retained crop residues and fluted roller seed metering synchronized with fertilizer application for precise input placement. Field evaluations showed a 22% reduction in fuel consumption, improved soil moisture retention, and a 12–15% increase in crop emergence compared to conventional tillage planting. The implement proved effective for energy saving and sustainable multi-crop farming.

Kumar et al. (2020) designed a combined tillage tool integrating a subsoiler, rotavator, and seed drill. The implement reduced the number of passes from three to one, lowered energy input by 32%, and improved effective field capacity by 22%. The system was particularly effective in clay loam soils, where soil pulverization and seedbed preparation were achieved in a single operation.

Naik (2023) developed a basin seeder with an integrated watercourse attachment specifically designed for onion cultivation in Vertisols. The implement combined basin formation, seed placement, and watercourse construction into a single operation, thereby reducing the number of field passes required. Field evaluations demonstrated a field efficiency of 80-82% and a reduction in sowing costs by approximately Rs. 3040 ha^{-1}, underscoring its operational efficiency and economic advantage for smallholder farmers. The study highlighted the potential of such multi-functional implements in improving timeliness and reducing the overall cost of cultivation in onion-based farming systems.

These studies demonstrate a strong shift towards integrated, multi-functional sowing technologies, ranging from seed-cum-fertilizer drills to sensor-assisted planters. Such machines improve timeliness, reduce operational costs, and support diversified cropping systems, making them vital for sustainable multi-crop farming.

Watercourse Formation Machinery : Watercourse and furrow construction are critical operations for efficient irrigation management in multi-crop farming systems. Traditionally, these tasks are performed manually, consuming considerable labor and time, and often leading to irregular water distribution. Mechanization has therefore focused on the development of combined machinery that integrates furrow formation, basin listing, or seeding with watercourse preparation, thereby enhancing timeliness and water-use efficiency.

Naik (2023) reported the Development of a basin seeder with watercourse attachment for onion cultivation in Vertisols. The implement consisted of a tractor-mounted basin lister frame integrated with a seed metering unit and a watercourse maker. Evaluation under field conditions demonstrated field efficiency of 80–82% and sowing cost reduction of □3040 ha^{-1}. In addition to reducing labor, the machine ensured uniform seed placement and proper water distribution within basins, which is essential for onion cultivation.

Patel and Patel (2015) developed a tractor-operated furrow opener-cum-seeder specifically designed for maize cultivation. The implement incorporated furrow openers mounted ahead of

seed tubes, enabling simultaneous furrow formation and seed placement. Field evaluations reported a field capacity of 0.89 ha h^{-1} and consistent seed placement depth, thereby ensuring uniform crop establishment. The integration of furrow construction and sowing within a single pass eliminated the need for separate operations, resulting in improved timeliness and reduced labor and operational costs.

Chaudhari et al. (2018) worked on a tractor-operated watercourse maker for Vertisol regions. The machine was fabricated with angled soil-cutting blades arranged on a toolbar to form continuous water channels across the field. Field evaluations revealed a field efficiency of 74% and a 65% reduction in labor requirement compared to manual channel construction. The watercourses were uniform and facilitated improved soil moisture retention during crop growth.

These studies collectively demonstrate that the integration of watercourse and furrow formation with sowing or basin listing provides multiple benefits, including reduced labor, improved timeliness, cost savings, and better irrigation efficiency. For multi-crop farming systems, where diverse crops with variable water needs are cultivated, such machinery ensures reliable irrigation management and improved crop performance.

Discussion and Emerging Trends in Combined Machinery : The reviewed literature clearly indicates a progressive shift in farm mechanization from single purpose implements to multi-functional combined machinery designed to optimize time, labour, and resource use in multi-crop farming systems. This transformation is driven primarily by the need to reduce operational costs, minimize soil compaction through fewer field passes, and enhance input use efficiency under diverse cropping conditions.

One consistent outcome across studies is the operational advantage of combined machinery in terms of cost and energy savings. Cultivator-cum-seed drills and roto-till drills (Verma et al., 2015; Kumar et al., 2020) demonstrated fuel savings of 20–25% compared to conventional separate operations, while basin lister-cum-seeders (Muthamiselvan et al., 2004; Kadam, 2020) improved timeliness and conserved soil moisture effectively in Vertisol regions. Similarly, watercourse and furrow formation machinery (Naik, 2023; Chaudhari et al., 2018) reduced labor requirements by up to 65%, addressing one of the most critical constraints in Indian agriculture high dependence on manual labor. Another notable trend is the integration of precision and automation technologies into traditional farm machinery. For instance, the Arduino-based automated basin lister (Kove et al., 2022) allowed variable basin length adjustment, while precision seed metering and monitoring systems (Shang et al., 2020; Zhang et al., 2023) ensured singulation accuracy above 95% and monitoring errors below 2%. These advancements illustrate the convergence of mechanical engineering with electronics and information technology, highlighting the role of smart mechanization in the future of agriculture. For Indian smallholder farming systems, the emphasis on lightweight, low-cost, and adaptable designs is particularly significant. Implements such as manually operated seed drills for terraced fields (Singh and Vatsa, 2007), multi-crop seed-cum-fertilizer drills (Verma and Gupta, 2016), and basin seeders with watercourse attachments (Naik, 2023) demonstrate adaptability across cereals, pulses, and vegetable crops. Their affordability and versatility make them highly suitable for fragmented landholdings and diversified cropping patterns, which dominate Indian agriculture.

The reviewed works also reflect the

increasing influence of conservation agriculture on machinery design. Strip-till drills (Chaudhari and Patel, 2016) and zero-till planters (Sharma et al., 2017) minimize soil disturbance, reduce erosion, and conserve soil moisture. When combined with precise fertilizer placement and seed metering, these implements not only enhance sustainability but also align with global efforts toward climate-resilient farming systems. Despite these achievements, challenges remain in the areas of scaling innovations, affordability, and farmer adoption. Many advanced prototypes remain confined to research stations and have not yet reached commercial scale. Furthermore, adoption requires adequate training and awareness, as multifunctional implements demand higher operational skills than conventional equipment.

Conclusion

The literature reviewed demonstrates a clear and consistent trend towards the development of combined agricultural machinery capable of performing multiple field operations in a single pass. Such machinery-ranging from basin lister-cum-seeders and furrow opener-cum-seeders to cultivator-cum-seed drills and roto-till planters-has shown substantial potential in addressing the pressing challenges of labor scarcity, high operational costs, and untimely field operations faced by farmers in India and other smallholder-dominated regions.

The key outcomes reported across studies include notable improvements in field efficiency (70–85%), significant reductions in fuel consumption (20–25%), and measurable savings in labor and operational costs (up to Rs. 3000 ha^{-1}). Importantly, these machines have enhanced soil moisture conservation, crop establishment, and irrigation efficiency, which are critical for ensuring sustainable productivity in multi-crop farming systems. An emerging frontier in this domain is the incorporation of precision and automation technologies. Automated basin listers, vacuum seed metering devices, and photoelectric monitoring systems illustrate how conventional machinery is evolving into smart mechanization platforms. These innovations not only improve input-use efficiency but also align agricultural practices with the principles of climate resilience and conservation agriculture. Despite these advances, challenges persist in terms of commercial scalability, affordability, and farmer adoption. Many of the reviewed prototypes remain confined to experimental use. Therefore, there is an urgent need to accelerate technology transfer, customization for regional cropping systems, and farmer training to enable widespread utilization.

In conclusion, combined agricultural machinery represents a vital pathway for achieving sustainable intensification, cost reduction, and resource efficiency in multi-crop farming systems. With continued innovation and effective dissemination, such machinery can play a transformative role in enhancing farm profitability, ensuring food security, and supporting the long-term sustainability of Indian agriculture.

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