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MP Shrikantagouda
SMS- Agri. Engineering, BCT-KVK, Visakhapatnam, Andhra Pradesh, India

Dr. K Sailaja
Senior Scientist and Head, BCT-KVK, Visakhapatnam, Andhra Pradesh, India

Dr. V Prasad Rao
SMS- Agronomy, BCT-KVK, Visakhapatnam, Andhra Pradesh, India

B Nagendra Prasad
SMS- Plant Pathology, BCT-KVK, Visakhapatnam, Andhra Pradesh, India

Dr. JV Prasad
Principal Scientist, Agril. Entomology, ATARI Zone - X, Andhra Pradesh, India

Dr. Shaik N Meera
Meera: Director, ATARI Zone - X, Andhra Pradesh, India

Corresponding Author:
MP Shrikantagouda
SMS- Agri. Engineering, BCT-KVK, Visakhapatnam, Andhra Pradesh, India

Mechanization in paddy farming: A pathway to higher profits and lower costs in paddy fields of coastal A.P

MP Shrikantagouda, K Sailaja, V Prasad Rao, B Nagendra Prasad, JV Prasad and Shaik N Meera

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Abstract
Paddy cultivation in Andhra Pradesh has traditionally relied on labor-intensive transplanting methods, resulting in high cultivation costs. However, due to increasing labor shortages driven by urbanization and industrialization, farmers in the Anakapalli district have begun adopting mechanized practices such as direct seeding, mechanical weeding, drone spraying, and combined harvesting to reduce costs and improve efficiency. The BCT-Krishi Vigyan Kendra (KVK) supported this transition by providing custom hiring services for agricultural implements, conducting on-field demonstrations, farmer field schools, and training programs. To evaluate the overall impact of mechanization, Frontline Demonstrations (FLDs) were conducted in the mandals of Rambilli, Atchutapuram, and Munagapaka. The results showed that mechanized practices reduced the total cost of cultivation by ₹39,825 per hectare lowering it to ₹46,250/ha compared to ₹86075/ha for traditional methods. Additionally, yield increased by 13.7%, and net returns improved by 114%. Beyond cost savings, mechanization also addressed peak-time labor shortages and facilitated timely pest management such as controlling the climbing cutworm through drone technology. Overall, mechanization reduced drudgery, enhanced operational efficiency, and proved to be a sustainable solution for modern paddy farming.

Keywords: Direct sowing of paddy, single row power weeder, drone technology, combined harvester

Introduction
Rice, often referred to as the "global grain," is a staple food for more than half of the world's population. Approximately 90% of global rice production occurs in Asian countries, contributing between 50% to 80% of the daily caloric intake for the region's population (Shivashankarmurty *et al*., 2020) [5]. In India, rice is the most important and widely cultivated food crop, with Andhra Pradesh being one of the leading rice-producing states. In Andhra Pradesh, the total area under paddy cultivation is about 2.14 lakh hectares, of which 1,17,608 hectares fall within the Visakhapatnam district. This district, being part of a Special Economic Zone (SEZ), has undergone significant industrialization. Consequently, a large portion of the rural workforce has shifted from agriculture to industrial jobs, leading to acute labor shortages for key farming operations. This shortage is particularly evident during labor-intensive stages like transplanting, weeding, and harvesting; resulting in increased cultivation costs.Additionally, the younger generation shows little interest in agriculture due to the physical strain associated with traditional methods, such as working in puddled fields under harsh weather conditions. They tend to seek industrial employment, treating agriculture as a secondary income source. This shift further escalates the labor cost in major crops like paddy.

Climate change has also worsened the situation by disrupting rainfall patterns. In recent years, water availability for irrigation has been delayed until August or even later, adversely affecting timely crop establishment. To address these compounding challenges, BCT-Krishi Vigyan Kendra (KVK), Visakhapatnam, has been proactively promoting agricultural mechanization. Through demonstrations and training programs, the KVK has introduced a range of mechanized solutions, including land preparation, direct sowing, mechanical weeding, drone spraying, and combined harvesting.

These interventions aim to reduce labor dependency, cut down on drudgery, lower the overall cost of cultivation, and ensure timely completion of farm operations. The adoption of mechanization not only helps farmers cope with labor shortages and climate uncertainties but also significantly enhances productivity and profitability in paddy cultivation.

Materials and Methods

BCT-KVK focuses on the welfare of farmers in the district. KVK has conducted numerous training programs on mechanization in paddy cultivation and has carried front line demonstrations on machinery used in paddy farming during Kharif -2024. KVK follows village-based approach, organizing training programs and demonstrations on machineries in Paddy mainly concentrated on 1) Importance of summer ploughing and land preparation with Rotavator for direct sowing of Paddy 2) sowing equipment like seed-cum-fertilizer drill or seed-cum-fertilizer planter for direct seeding of paddy 3) weeding operation with mechanical weirder like Single row Paddy Power weeder 4) Spraying operation with drone technology 5) Harvesting operation with combined harvester. Along with effect of machinery utilization collected data on Growth and yield parameters like plant height, number of tillers, number of hills, Panical length, Number of grains, grain weight, test weight and yield.

Seed-cum-Fertilizer Drill

This is a tractor-drawn implement made of cast iron and plastic. The power requirement for operating the seed-cum-fertilizer drill ranges from 30 to 50 HP. The seed metering mechanism is of the cup-feed type, and the seed box has a capacity of 50 kg. It can sow 9 rows of seeds at a time with a plant-to-plant spacing of 30 cm, using adjustable furrow openers to ensure uniform depth. The field capacity varies between 2.4 ha/day to 3.2 ha/day.

Seed-cum-Fertilizer Planter

This implement is similar to the seed drill but features an inclined plate metering mechanism instead of a cup-feed mechanism.

Key Features of Both Implements

The use of mechanized seeding techniques significantly reduces labor costs by eliminating the need for nursery rising, pulling, puddling, and transplanting. It ensures uniform seed sowing and maintains an optimal plant population, leading to better crop establishment. Additionally, the seed rate requirement is reduced, saving approximately 35 kg per ha. This method also accelerates crop maturity by 7 to 10 days compared to manual transplanting, allowing for timely harvesting and improved farm efficiency. Progressive farmers' fields were selected for on-farm trials with proper drainage facilities and regulated water management. The variety cultivated using direct-seeded rice technology with the seed-cum-fertilizer drill/planter was RGL-2537.

Weeding Operation with Single-Row Paddy Power Weeder

The weeding operation was conducted using a single-row paddy power weeder with a 2 HP capacity, four-stroke petrol engine. The weeding width is adjustable between 140 mm to 250 mm. The machine is equipped with rotating blades running at 176 RPM and is centrally driven. Due to its lightweight design (~14.5 kg) and ease of operation, it can be efficiently used in puddled paddy field.

Key Features of the Power Weeder

The machine is easy to operate, requires low maintenance, and is lightweight, making it convenient for farmers. It can be used in row spacing between 150 mm to 310 mm, allowing flexibility in different crop conditions. Weeding is performed at 20 and 40-day intervals after sowing or transplanting, ensuring effective weed control. Additionally, the machine is designed to be operated by a single person with minimal effort, enhancing efficiency in farm operations.

Agricultural drone technology

A hex copter agriculture drone, weighing 25 kg with a 10-liter spraying tank capacity, was used for spraying operations to combat sheath blight & climbing cutworms in paddy fields with speed of 4.5 m/sec and maintained 1m. The use of this advanced technology has significantly improved efficiency in spraying operations, especially in puddled fields where manual spraying is labor-intensive and time-consuming.

Key Features of Agricultural drone technology

The agriculture drone helps overcome the drudgery of spraying operations, reducing physical effort and ensuring uniform application. Additionally, it minimizes chemical usage by 25%, reducing the environmental impact and input costs for farmers. The drone also significantly reduces water consumption by 95%, making it a highly water-efficient solution for crop protection. Moreover, the time required for spraying operations is cut by 97%, allowing farmers to cover larger areas in a shorter period. This mechanized approach enhances precision, reduces labor dependency, and improves overall farm productivity.

Chine type combined harvester

The use of a combined harvester minimizes the requirement of 24 labourers for harvesting, heaping, and threshing, thereby reducing manual effort and drudgery. Additionally, it lowers the cost of harvesting from ₹12,000 to ₹3,200 per acre, making paddy cultivation more cost-effective and sustainable for farmers.

Key Features of the Combined Harvester

A chain-type combined harvester was used for harvesting paddy in wet and soft field, it consist 2.4m cutter bar width, grain storage capacity was 1000 kgs, field capacity was 0.4 ha/hr, harvesting efficiency was 95-98%, significantly improving efficiency and reducing labor dependency.

Results and Discussion

Frontline demonstrations on mechanization in paddy cultivation was conducted during Kharif 2024. These demonstrations clearly highlighted the effectiveness of mechanization in reducing dependence on manual labor 121%, thereby addressing labor shortages and minimizing drudgery in farm operations. Mechanization significantly reduced the time required for key agricultural activities such as sowing, transplanting, spraying, and harvesting. By replacing traditional, labor-intensive practices with efficient machine-based alternatives, farmers were able to complete operations more quickly and at a substantially lower cost. This timely and precise execution of tasks improved crop management, resulting in higher yields and increased net income for farmers.

Table 1: Comparative analysis of Mechanization with Farmer practice

SI No.	Particulars	Mechanization						Traditional Practice					
		Land Preparation with cultivator & Rotavator	Sowing with seed drill	Weeding with Mechanical weeder	Drone Spraying	Harvesting with Combined Harvester	Total	Land Preparation with cultivator & Cage wheels	Manual Transplanting	Manual Weeding	Manual Spraying	Manual Harvesting to Threshing	Total
1	Cost of cultivation (Thousand Rs./ha)	9.25	3	9	4	8	33.25	12.7	12.75	13.5	6.75	25.5	71.2
2	Man days required per ha	1	1	10	1	1	***14***	2	30	45	6	65	148
3	Field capacity (ha/hr)	0.4	0.4	0.06	2.6	0.3	3.76	0.4	0.0044	0.0083	0.1	0.0055	0.5182

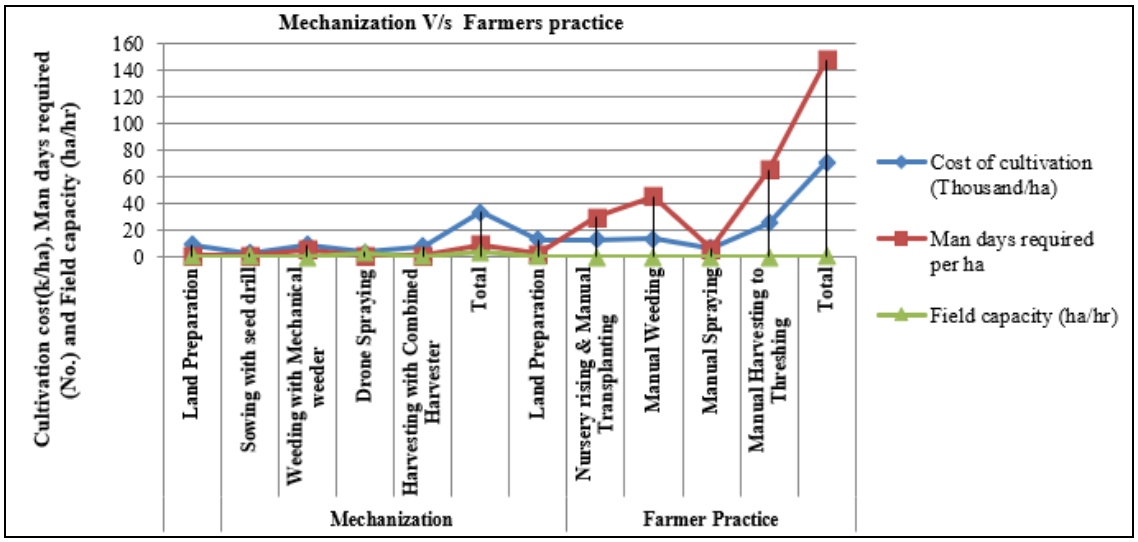

Fig 1: Graphical representation of Mechanization impact on Paddy

Table-1 presents a comprehensive comparative analysis of mechanized versus traditional paddy cultivation practices, focusing on key parameters such as cost of cultivation, labor requirements, and field efficiency. The findings clearly highlight the significant economic and operational benefits of adopting mechanization in paddy farming.

Cost of Cultivation

Mechanized farming operations significantly reduced the cost of cultivation. The cost under mechanization was ₹33,250 per hectare, whereas the traditional farmer practice incurred a much higher cost of ₹71,200 per hectare. This represents a cost saving of ₹37,950 per hectare, or a reduction of approximately 53.3%.

- The cost savings were most evident in land preparation (₹9250 vs ₹12700) sowing (₹3,000 vs ₹12,750), weeding (₹9,000 vs ₹13,500), and Drone spraying (₹4,000 vs ₹6,075).
- Combined harvester (₹8,000/ha) was also more efficient and economical compared to manual harvesting (₹25,500/ha). Such cost reductions make mechanization particularly beneficial for small and medium farmers seeking to reduce input costs.

From the results, it was observed that the reduction in the cost of cultivation for land preparation under mechanization was mainly due to the use of cultivator and rotavator, which are efficient and require less time and fuel. In contrast, under the farmer practice, land preparation was done using a cultivator followed by puddling operations with cage wheels and disc harrow, which involved additional steps, labor, and fuel ultimately leading to increased cultivation costs. Similarly, in the mechanized practice, direct sowing was carried out using a seed-cum-fertilizer drill, which reduces cultivation cost by 76.4%, seed requirement by 46.6%, water requirement saving nearly by 30% and saves time. However, under traditional farmer practices, Transplanting involved raising a nursery, followed by manual transplanting into the main field a labor-intensive and time-consuming process. This significantly increased the overall cost of cultivation in traditional methods compared to mechanized sowing.

Weed growth tends to be more vigorous and challenging in sandy loam soil compared to other soil types, primarily due to its balanced texture, good drainage, and moderate nutrient and moisture retention. These conditions create an ideal environment for the emergence and proliferation of a wide variety of weed species hence traditional method requires more lobors, hence reduction in weeding cost compared to traditional method was 33.3%.

In the mechanized method, drone spraying was used to control sheath blight with Hexaconazole (400 ml/acre @ ₹250) and climbing cutworm with Bifenthrin (500 ml/acre @ ₹350), costing ₹500/acre for spraying. It reduced chemical use by 25% and minimized labor, time, and physical strain. In contrast, traditional methods involved manual spraying with knapsack sprayers, requiring ₹500 for spraying labor, ₹200 for support labor, and ₹600 for chemicals. For mature crops, additional ₹700 was needed to clear paths for spraying, making the process more laborious and costly mainly to control climbing cut worm.

Combined harvestor will cover the operations like harvesting, threshing and winnowing. Where as in traditional practice harvesting & heaping was done by manually after this threshing with multi crop thresher with help of labor. Compared to traditional practice reduction in harvesting cost was 68.6% was observed.

Man-Days Required

Mechanized cultivation drastically reduced the human labor requirement to just 14 man-days per hectare, compared to 148 man-days under traditional methods.

- Manual weeding, transplanting and harvesting operations under farmer practice consumed the majority of labor days (30, 45 and 65 man-days respectively), while the same operations under mechanization required 14 man-days, due to use of weeder, seed drills and combined harvester.
- This 90.5 % reduction in labor demand directly addresses the challenge of agricultural labor shortages and rising wage costs.

In traditional paddy cultivation, labor demand is high requiring male workers for bund trimming and nursery rising, about 30 laborers (mainly women) for transplanting, 45 for weeding, 6 for spraying, and over 65 for harvesting, heaping, and threshing. This increases cultivation costs, time, and drudgery, especially for women. In contrast, mechanization reduces labor, speeds up operations, and ensures timely, efficient crop management.

Field Capacity

Mechanized operations demonstrated superior field capacity. The total combined field capacity across all mechanized operations was 3.76 hectares per hour, compared to just 0.5182 hectares per hour using farmer practices.

- Notably, drone spraying (2.6 ha/hr), Sowing with seed drill (0.4 ha/hr), Harvesting with combined harvestor (0.3 ha/hr) & mechanical weeding (0.06 ha/hr), were far more time-efficient than their manual counterparts (0.1 ha/hr, 0.004 ha/hr, 0.005 ha/hr and 0.0083 ha/hr respectively).
- The higher field capacity enables timely completion of critical operations such as sowing, weeding, spraying, and harvesting, which can directly influence crop health and yield.

Growth Parameters of Mechanized V/s Famers practice of Paddy cultivation

Paddy grown under seed to seed Mechanized method had influence on growth and yield parameters as compare to manual transplanting method (Table 2). The results of field demonstrations indicated that, growth parameters of paddy like plant height (119.6 cm), no. of tillers/hill (25.3) and number of hills/m2 (32) recorded higher in mechanised Paddy cultivation. Whereas, in case of manual transplanting, plant height, number of tillers/hill and number of hills/m2 were 111.3cm, 20 and 41, respectively. The yield attributes like Panicle length, Number of grains/panicle, t and test weight were recorded higher values of 17.3 cm, 165, 5.15 g and 31.2g, respectively in mechanised transplanting during.

SI No.	Particulars	Mechanization	Farmers practice
1	Plant height (cm)	119.6	114.3
2	No. of Tillers	25.3	17.6
3	No. of Hills/m2	32	26
4	Panicle length (cm)	17.3	16.9
5	No. of Grains/Panicle	210	170
7	Test weight (g/1000 grains)	15.9	13.8

Table 2: Economics of Mechanization V/s Farmer Practice.

SI No.	Particulars	Mechanization	Farmers practice	Difference
1	Grain yield kg/ha	6,090	5,250	840
2	Grain value (₹23/kg) Gross returns	1,40,070	1,20,750	19,320
3	Straw yield kg/ha	6,980	6,498	482
4	Straw value (₹1/kg)	-	6,498	0
5	Total cost of cultivation	46,250	86,375	-40,125
6	Net income	93,820	34,375	59,445
7	C: B Ratio	3.03	1.40	1.63

Table-1 clearly highlights the positive impact of mechanized operations in comparison to traditional paddy farming methods. Paddy cultivation involves various stages such as land preparation, sowing, weeding, spraying, and harvesting, along with other activities like irrigation, fertilizer application, and granule broadcasting, all of which contribute to the total cost of cultivation, as shown in Table-3, mechanization led to an increase in yield up to 13.7%. Regarding paddy straw, manual harvesting results in long, intact straw, which is ideal for traditional uses like cattle fodder providing additional income to farmers but it is labor-intensive and time-consuming. On the other hand, combined harvesting is fast and cost-effective but produces chopped straw, which has limited fodder value and hence does not generate income from straw. The total reduction in cost of cultivation was 46.26% per hectare compared to traditional methods. The net income increased by ₹52,647 per hectare i.e 127.8%, primarily due to cost savings and higher yields. The Cost-Benefit (C:B) ratio for mechanized farming was 3.03, significantly higher than 1.63 for traditional practices, clearly demonstrating the economic advantage of adopting mechanization in paddy cultivation.

Conclusion

Mechanized paddy cultivation proved to be significantly more efficient and economical compared to traditional methods. The total cost of cultivation was reduced by 42.26% through mechanization (₹39,825 savings out of ₹86,075 total traditional cost). The net income increased by 127.86% (₹52,647 gain compared to traditional net returns). Additionally, mechanization improved yield by 13.79%, contributing further to profitability. The Cost-Benefit (C:B) ratio increased by 115.8%, from 1.63 (traditional) to 3.03 (mechanized). These figures clearly demonstrate that mechanization not only reduces input costs and labor dependency but also enhances productivity and overall farm profitability.

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