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RESEARCH

IMPACT ASSESSMENT OF FARM MECHANIZATION AND AGRONOMIC CONSEQUENCES IN HDPS COTTON TO ENHANCE PRODUCTIVITY IN RANGAREDDY DISTRICT, TELANGANA

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Abstract: Cotton (*Gossypium hirsutum* L.) is a major commercial crop in the rainfed regions of India and accounts for 23% of the total global production, playing a major role in sustaining the livelihood of 6 million cotton farmers, also known as “white gold”.In cotton cultivation lack of awareness among growers about the HDPS method and low adoption of agricultural mechanization Technologies has prevented farmers of Telangana from maximizing production benefits. The study aimedto evaluate the mechanization in the newly developed production technology High Density Planting System (HDPS) of cotton with crop spacing of 90 x 15 cm. The introduction of appropriate machinery operations in HDPS cotton greatly reduced the time up to 82%and labour requirement. The HDPS in combination with the mechanized method increased production per unit area by decreasing plant spacing from 45 x 15 cm and increasing plant density from 9,800 to 29,500 plants per acre. The practices gave maximum yield in HDPS cotton cultivation in the 27-32 q/ha range. The B:C ratio for mechanized HDPS cotton cultivation was 2.64 as compared to 1.44 for conventional cultivation.

Keywords: Cotton crop, Mechanization, Pneumatic planter, Drone, Stalk shredder

INTRODUCTION

Cotton is one of India's most important fibre and cash crops and plays a major role in the country's industrial and agricultural economy. It is cultivated in tropical and subtropical regions of more than seventy countries. India's textiles and clothing industry is one of the mainstays of the country's economy and accounted for about 10.5% of India's total merchandise exports in 2021-22. India accounts for 4.6% of world trade in textiles and apparel, and nearly about 60% of the fibrefor Indian textiles comes from cotton. Cotton cultivation provides income to more than 250 million people worldwide and employs about 7% of the workforce in developing countries. About 67% of India’s cotton is produced in rain-fed areas and 33% on irrigated lands Recent statistics reveal that India (13.40 million ha) has more than a third (32.94 million ha) of the world under cotton cultivation, with a productivity of 487 kg/ha, when compared to the global productivity of 775 kg/ha. Which indicates large productivity gapfor cotton? Cotton seed consists of relatively high-quality oil and protein in the ratio of 21% and 23%, respectively (Nalayini et al., 2018 and Stesi *et al*., 2023).

Currently cultivated cotton hybrids are plant varieties with maximum biomass production and rapid growth. The ratio of boll formation to boll retention should be low at this stage. This should be compared with the requirements of crop inputs such as irrigation, fertilizer and different character maturity periods, yield per unit area and productivity per day (Makamov *et al*., 2023).A new technology has become available High Density Planting System (HDPS), early maturing, compact or semi-compact lines, as well as varieties that give maximum yield of seed cotton at minimum cultivation cost suitable for rainfed and irrigated conditions. Given the growing global population and the increasing demand for food and clothing, the HDPS has emerged as an alternative strategy to conventional methods, with well-established agronomic techniques for enhancing input use efficiency, yield, profitability and complete mechanization including mechanical harvesting (Nalayini *et al*., 2018and Lin *et al*. 2021).This newly developed concept of HDPS has the potential to improve rainfed cotton productivity in India with straight varieties as a viable option at reduced production costs. Under HDPS conditions, the plants typically produce fewer bolls compared to seeded cotton but maintain a higher total number of bolls per square meter.

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The HDPS of cotton is designed for shallow to medium soils and mirrors the agronomic benefits of ultra-narrow-row cotton. This system employs a close-row configuration with 90 x 15 cm spacing, leading to rapid canopy closure and higher plant populations. The indeterminate growth habit of cotton allows it to adapt its fruiting patterns based on plant density, making it suitable for various soils and climate conditions.

A special project on cotton approved by the Ministry of Textiles, Govt. of India entitled "Targeting Technology to Agro-Ecological Zones Large Scale Demonstrations of Best Practices to Enhance Cotton Productivity" under the National Food Security Mission (NFSM). The project is being implemented through the nodal center ICAR-Central Institute of Cotton Research (CICR, Nagpur on PPP (Public Private Partnerships) mode in the identified clusters through a value chain approach by collaboration with various institutions in the country. In Rangareddy District Telangana State, it has selected 3 clusters each from Madugu, Amanagal and Manchalmandals in 16 villages with 88 farmers and 109 hectares in association with ICAR-CRIDA, Krishi Vigyan Kendra-Ranga Reddy for this research. The present study was taken up to demonstrate to the adopted clusters and carry out research work with various technologies to assess the impact of agronomic practices of HDPS in combination with farm mechanization to enhance productivity in the Rangareddy district.

Early maturing compact two Bt cotton cultivars with shorter sympodia namely RASI Swift RCH-971 and RCH-929from RASI Seeds Pvt Ltd, which are recommended for HDPS have been selected for this study andare sown using a pneumatic planter. The plant population was increased from 9800 to 29500 plants per acre and uniform sowing depth was ensured.

MATERIALS AND METHODS

The study was conducted in CRIDA Research Farm, Hayathnagar during Kharif 2023-2024. The topography of the experimental field was very uniform, level and with good drainage. The geographic latitudes of the experimental site are 17°20'26.93" North latitude and 78°35'30.24" East longitude. The research farm is located in the southern agroclimatic zone of Telangana with tropical wet and dry climatic conditions, bordering a hot semi-arid climate (Köppen climate classification BSh) of seasonal, the Köppen climate classification divides climates into five main climate groups, with each group being divided based on the pattern of precipitation and temperature. The area extent of the field is 3000 square meters.

Table 1. Cultivation practices followed in the experiment.

Particulars	HDPS	Conventional
Field preparation	Tillage done using cultivator once and twice disc harrow and planking once	Tillage done using cultivator once and twice disc harrow and planking once
FYM application	@ 2-5 tonnes/acre FYM along with P_2O_5	Nil
Sowing date	12th June 2023	14th June 2023
Crop spacing	90 cm x 45 cm	90 cm x 45 cm
Sowing method	Mechanical- using Pneumatic planter	Manual dibbling
Seed rate / acre	2375 gm	1425 gm
Plant population	29,500 plants per acre	9800 plants per acre
Weed Control: Preemergence herbicides	Pendimethalin 38.7% CS @ 700 ml/acre within 24-48 hours of sowing	Pendimethalin 38.7% CS @ 700 ml/acre within 24-48 hours of sowing
Irrigation method	Flooding - Given as per need	Flooding - Given as per need
Intercultural & Weeding operation	Mechanical (20 and 40 days after sowing) using tractor operated implements	Manual weeding (20 and 40 days after sowing)
Nutrient management	36:18:18 kg per acre (N:P:K) Used machine and manual	Recommended dose
Plant protection Spraying operation	Applied timely as per requirement.	Applied timely as per requirement
Cotton picking	Manual handheld cotton pickerused	Manual picking
Cotton stalk management	CRIDA Crop stalk Shredder	Nil

Criteria for selecting cultivars for HDPS

The introduction of the HDPS was pioneered by Briggs et al., 1967, who implemented narrow-row planting with compact and early-maturing cotton varieties for sustainable production at reduced costs in the Indian context. The adoption of HDPS is increasing, particularly in rainfed areas due to low productive soils. The planting was taken up with

RCH-929 and RCH-971 due to its compact plant structure, and short fruiting branches that retain more of the first bolls. Larger boll size (> 4g) cultivars, early maturing and synchronous boll bursting cultivars are amenable to machine picking. The selected cultivars have medium-duration early flowering, synchronized boll bursting and good tolerance to TSV (Tobacco Streak Virus) & sucking pest complex. Several plant growth attributes from germination to harvest were recorded at frequent intervals and usage of plant growth regulator Mepiquat Chloride was also noted and boll weight is recorded in grams.

RESULTS AND DISCUSSION

Weather conditions

The mean monthly temperature recorded during the crop growth period varied from 32.7°C in June to 21.9°Cin December and maximum and minimum temperatures recorded were 36.1°C and 18°Crespectively, in June and December of the year. The total rainfall received is 555.1 mm & distributed over 55 rainy days, with the highest in August (24 days) and the lowest in October (0 days). The average relative humidity for this period is 88.2%.The weather parameters are presented in Fig 1.

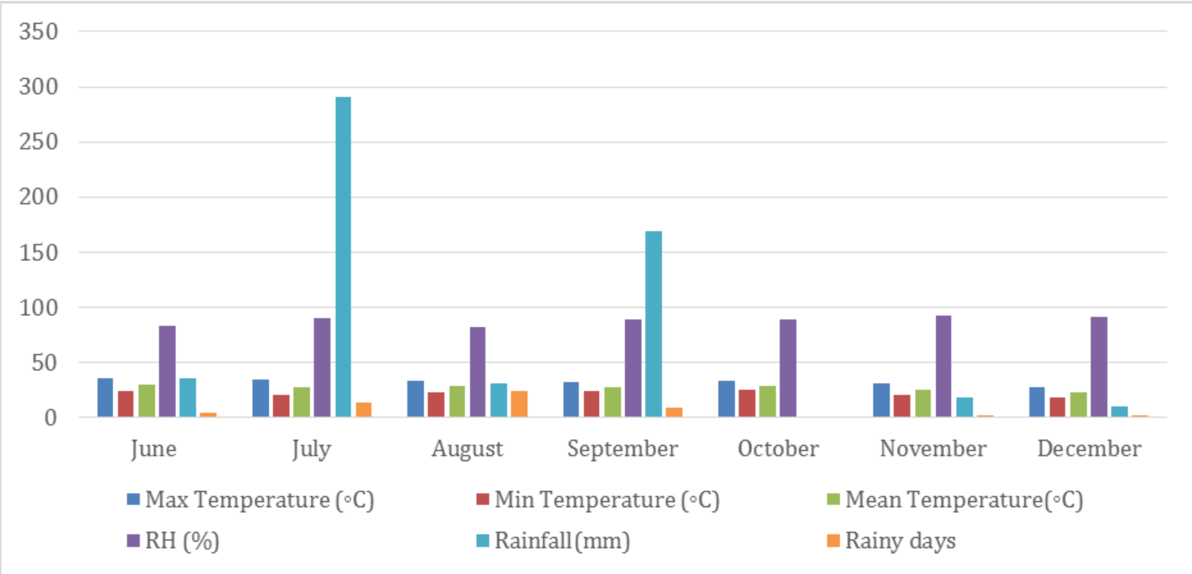


Fig.1: Weather parameters during the crop growth period in 2023

Soil characteristics and Fertilizer application

Cotton grows in various soils, from well-drained deep alluvial soils in the north to black and mixed soils in the central and southern parts of the country. Although partially tolerant of salinity, it is sensitive to waterlogging and prefers well-drained soil. The soil of the experimental site was red Alfisoland had good drainage properties. Soil analysis results before the experiment indicated that major nutrients were low in available form and zinc was deficient (Table 2).So, it is necessary to use the recommended dose of nutrients. In addition, micronutrients are low in quantity and the use of micronutrients is also recommended and the fertilizer dose was adjusted and applied according to the recommended fertilization requirements.

Table 2: Soil test results for the experimental site

Soil Properties	value	Status
pH	7.8	Basic
EC	0.08ms	Non-Saline
Available Nitrogen (kg/ha)	110.00	Low
Available phosphorus (kg/ha)	33.6	Low
Available potassium (kg/ha)	139.8	Medium
Copper	1.04	Low
Zinc	0.60	Deficient
Iron	5.20	Low
Manganese	13.20	Low

Fertilizers (36:18:18 kg/acre, N:P: K) are applied as per RDF for HDPS cotton as prescribed by CICR Nagpur.Phosphorus is applied as a basal dose, nitrogen (from Urea) in three doses and potassium (from MoP) at flowering. Half a dose of nitrogen was given as top dressing after 30 days of sowing in the ring method through urea, micronutrients are added if deficiency is observed (**Table 3**). PGR (Chamatkar is a local name) is used for optimal plant growth control. Manual fertilizer application is challenging and time-consuming & requires (20-30 working hours per hectare).Modern fertilizer applicators reduce back strain with a 5-6 kg capacity spring mechanism that delivers fertilizer directly at the plant's root zone. Fertilizers applied when the soil has enough moisture have recorded better use efficiency. Mechanical fertilizer application by adjusting the furrow openers row spacing of the planter took 1-2 machine-hrs and 1-2 man-hrs per hectare, achieving 90-95% reduction in time and enabled timely operations.

Table 3. Fertilizer applied doses at different stages of crop.

Fertilizer use schedule	Part of the recommended dose per Acre
Basal or at the time of sowing	1/3rd N, full dose of P and ½ dose of K
Squaring stage (40-45 days after sowing)	1/3rd N, ½ of K and 5 kg ZnSO4
Flowering and early boll formation stage (70-75 days after sowing)	1/3rd N + 2 kg Boron

Crop Growth Attributes and Yield

Plant height was measured from the base of the plant to the last fully open leaf at the tip. At the harvest stage, the height ranged from 95- 125 cm with a mean height of 110 cm at 90 x 15 cm spacing. This parameter concurs with the results obtained in a study by Venugopalan *et al*., 2016.A greater number of plants per unit area results in greater height per plant, possibly due to increased competition for sunlight and CO_2 (Stesi *et al*., 2023). The average number of monopodial branches recorded per plant was 01 and sympodial branches 20 in number. The average number of bolls per plant observed was 22, with an average boll weight of 5.5 grams. The yield of any crop depends on many factors such as soil quality, climate, soil moisture, etc. along with mechanization and seed types. The studies indicate that RASI SWIFT RCH-971 and RCH-929 yields in HDPS are comparatively higher than the conventional method of cultivation due to high plant population and with mechanized activities accomplished timely operations increasing input use efficiency(Ansari et al., 2003 and Kumar *et al*., 2017).As observed in different clusters, farmers prefer the HDPS method more than the RCH-929 variety RASI SWIFT RCH-971.The increase of yield as compared to the conventional method of cultivation was 75% higher in HDPS as the data indicates in Table 4.

Table 4. Crop growth attributes and Yield parameters of HDPS cultivation of RCH-971 and Desi variety in conventional practice.

Variety	Crop Period, days	Spacing cm	Plant population/ha	Mean values of various parameters					
				Plant height, cm	No of bolls /plant	No. of monopodial / plant	Sympodia /plant	Boll weight,gm	Yield, kg/ha
RCH-971	140	90x15	29500	110	22	01	20	5.5	2800
DESI variety	180	90x45	9,800	140	42	04	22	5.0	1600

Mechanized cultivation practices in HDPS cotton

Advances in agricultural mechanization introduced tools and machines that combined both animal and mechanical power a few decades ago, and slowly animal power was limited to one or two methods of production. Mechanization can save time and labor for small farmers, increase yields and reduces post-harvest losses while improving the quality of agricultural produce. Therefore, mechanization can hold the potential to substantially benefit small-scale farmers by improving their livelihoods and contributing to agricultural sustainability. The possible various mechanized options in this HDPS cotton cultivation were explored and the results were enumerated in this section.

Field preparation and Sowing

Conventional field preparation requires about 50-60 man-hours per hectare with a country plow, which involves laborious work, and 66 km of walking per hectare. Mechanized field preparation is carried out using a combination of different tillage implements such as a moldboardPlow, rotavator,disc harrow and cultivator, which not only reduces operation time but also supports in eradicating weeds, destroying soil pests and facilitates timely sowing of cotton.

In a prepared field using a double cultivator and disc harrow, seed planting was done with a 3-row air planter, reducing the planting time and ensuring good germination by placing the seeds in the soil at the correct depth (5-6 cm).This mechanical sowing ensured uniform seedling emergence; strong crop stands through efficient use of space as evident from the growth attributes of crop. Mechanized sowing required about 3 machine hours to complete a one-hectare field, which reduced the time by 80-90% compared to manual sowing.

Inter-cultivation &Weeding

Weed infestation is a major problem often encountered in crop production of majority of crops, which often competes for nutrients, light, and moisture, significantly reducing yields if left unchecked. Manual weeding requires 120-150 man-hours per hectare, which is labour-intensive. To achieve effective weed control pre-emergence application of pendimethalin, followed by hoeing with a tractor-drawn blade harrow twice (at 30 and 75 DAS), and intra-rowhand weeding as per requirement was adopted (Fig 2). This took 10 machine- hrs per hectare, a 90-95% reduction in total time, effectively address in glabor shortages. Modern solutions such as self-propelled power weeders and inter-row rotavators also stand as good choices depending on the machine's availability and farmers affordability.

Fig.2: Inter-cultivation operation in cotton using tractor-drawn blade harrow.

Plant protection operation

Plant protection is critical in cotton cultivation, and prompt spraying of pests is essential to prevent crop loss. Systematic monitoring using pheromone and sticky traps (4 traps per acre) was used to track pest populations. When the limits of insects are exceeded, the use of plant protection chemicals is started. Conventional manual hand compression knapsack sprayers are labor intensive, so modern methods such as boom sprayers and drone spraying with the growth regulator mepiquat chloride increase efficiency (Table 5). Mechanized spraying significantly reduced machine time, a total of 6 machine- hrs per hectare, an 85-90% reduction in time compared to manual hand compression sprayer use.

Table 5. Different sprayer work efficiencies in plant protection operation

Machinery	Tank capacity (litre)	Time, hr/ha	Work efficiency
Drone sprayer	10	0.33	303 times faster
Boom sprayer	200	2	50% faster
Knapsack power sprayer	20	8	12.5% faster

Cotton picking

Cotton picking is the final operation in crop production and accounts for 35% of total input costs. Conventional cotton cultivars are asynchronous and require a minimum 3 number of manual pickings, which cannot be mechanized due to unsynchronized ball bursting. The selected variety enables mechanized cotton picking using synchronized ball bursting with a high-capacity cotton picker. Early use of defoliators removes leaves, prevents dry leaf infestation in picked cotton and preserves quality. Battery-operated manual hand-held cotton pickers offer an alternative up to some extent. Manual cotton picking requires 300-400 man-hrs per hectare, while mechanized picking takes 150 machine-hrs, reducing the time by 57.5 % and improving the picking efficiency of seed cotton by50% (Table 6).

Table 6. Comparison between Manual picking and battery-operated cotton picker

Manual Picking	Battery operated Cotton picker
Picked 25 to 35 kg of seed cotton per day	Picked 40to50kgof seed cotton per day
High chances of impurities like human hair, dried leaves etc	Less chances of impurities
Time-consuming	Saves operational time to some extent
Occasionally result in skin damage or cuts on the fingers	Easy to handle and doesn't cause any damage to the human body

Cotton stalk Management

In HDPS cotton cultivation, it is very important to manage the stalks and open bolls residues to avoid interference with the next crop. Conventionally, farmers cut or pick the stalks with axes, and burn them after drying them in the fields, which releases greenhouse gases and pollutes the environment. Here, introduced the cotton shredder, a tractor-driven machine that shreds the stalks into small pieces and incorporates them into the soil to increase fertility. Studies have shown that it increases the yield of the next crop by an average of 10%. Manual stalk picking method Rs. 4375/- per hectare, tractor operated shredder costs Rs. 3000/- saving Rs. 1375/- per hectare. Manual stalk handling requires 15-18 man-days per hectare, but the shredder reduces this to 2.5machine hours.

Advantages of Mechanized Crop Production Operations in HDPS

A comparative study was also carried out between conventional and mechanized HDPS cotton cultivation practices in various field operations. Data indicates that conventional cultivation has lower field efficiency compared to mechanized methods. This leads to high energy requirements and increased costs for various field operations. Detailed study data on conventional and mechanized cotton cultivation was presented in Table 7and Table 8, respectively.

Table 7. Conventional Cotton Field Production Operations

Operation	Type of implements used	Field capacity (ha/hr)	Field efficiency (%)	Energy used (hp-h/ha)	Cost of operation (Rs/hr)
Seedbed preparation	Desi plough	0.25 - 0.4	60-80	216.7	1390
Sowing	Manual (dibbling) single row Seeding behind the plough	0.1 - 0.3	50-70	25.0	2300
Inter cultural operations	Manual using Khurpi and Bullock drawn blade harrow	0.058	50.9	3280.0	862
Spraying	Manually operated hand compression knapsack sprayer	0.016	75.0	265.0	238
Cotton picking	Manually hand picking	0.005 - 0.01	50.0	95-100	100-150
Stalk management	Manual management & burning	-	-	-	-

Table 8. Improved implements used for HDPS cotton cultivation.

Operation	Type of implements used	Field capacity (ha/h)	Field efficienc y, (%)	Energy used (hph/ha)	Cost of operation (Rs/hr)
Seedbed preparation	Tractor-drawn ploughing &rotavator	0.35-0.60	85.50	140	1600
Sowing	Tractor-drawn pneumatic cotton planter	0.4 -0.5	75.50	43.75	563
Intercultural operations	Tractor-operated 2-row blade harrow	0.25-0.30	76.45	50.72	377
Plant protection operation	Low horse Power tractor operated boom sprayer	3.77	75.32	3.97	27
	Drone sprayer	6-7	70.00	0.894	1100
Cotton picking	Cotton picker	--	--	---	1200 - 1500
Stalk management	Cotton stalk Shredder	0.35	84.00	100.00	830-850

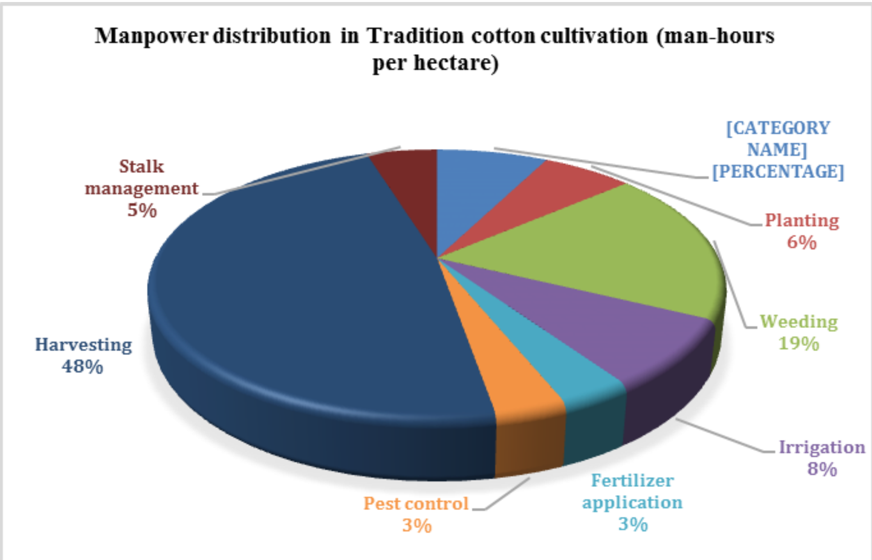
Average man-hours required for field operations in conventional and mechanized HDPS cotton cultivation show significant differences. Conventional methods are laborious and time-consuming, requiring multiple workers for tasks such as plowing, planting, weeding, and harvesting. Shifting from Conventional to mechanized cultivation using advanced machinery such as tractor-operated weeders and harvesters can significantly reduce the time and labor required for these tasks, increase productivity, reduce labour costs and increase overall farm productive efficiency. The average energy requirement in terms of man-hours required to carry out various agricultural operations and the percentage reduction in operation time under adaptive mechanized cultivation were presented in Table 9.

Table 9. The average field operational hours in conventional vs mechanized HDPS practice

Field operation	Conventional (Man Hours/ha)	Mechanized		Time Reduction (%)
		Man Hours/ha	Machine Hours/ha	
Land Preparation	50-60	1-2	5-10	60-80
Planting	40-50	1-2	2-3	90-95
Weeding	120-150	2-3	5-10	90-95
Irrigation	50-70	1-2	5-10	85-90
Fertilizer application	20-30	1-2	1-2	90-95
Pest control	20-30	1-2	2-3	85-90
Harvesting	300-400	2-3	5-10	95-98
Stalk management	30-40	1-2	2-4	85-90

Manpower distribution for farm operation in Conventional vs mechanized HDPS

In conventional cotton cultivation, distribution of manpower on various farm operations indicates that harvesting is the most labor-intensive at 48%. Weeding and harvesting together consume half of the total labor and energy input. By shifting from conventional to mechanized cultivation practices, these tasks can be handled more efficiently and timely, increasing productivity significantly. When machine picking is used the energy required for harvesting falls to 18%. (Fig3 and 4).



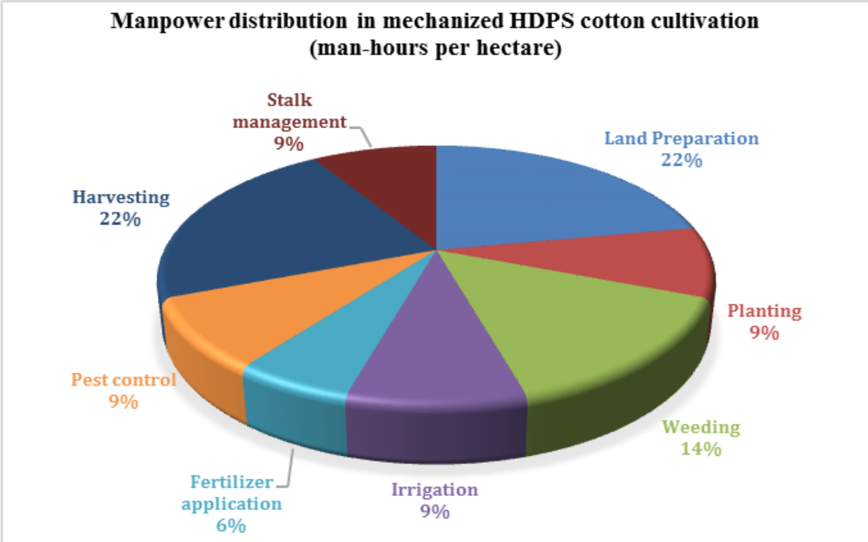


Fig 3: Mean time spenton farm operations in conventionalvs mechanized HDPS cultivation

Shifting from conventional to mechanized HDPS cotton cultivation will result in significant time reduction in various farm operations. Modern machines can perform tasks like plowing, planting, weeding, and harvesting more efficiently as compared to manual labor. This change not only increases productivity by completing tasks promptly but also significantly reduces the energy and labor required. The reduction in time for these activities depicted in Figure 4, highlights the advantages of mechanized farming over conventional methods. The mean time reduction in various farming operations was 82% compared to conventional cotton cultivation.

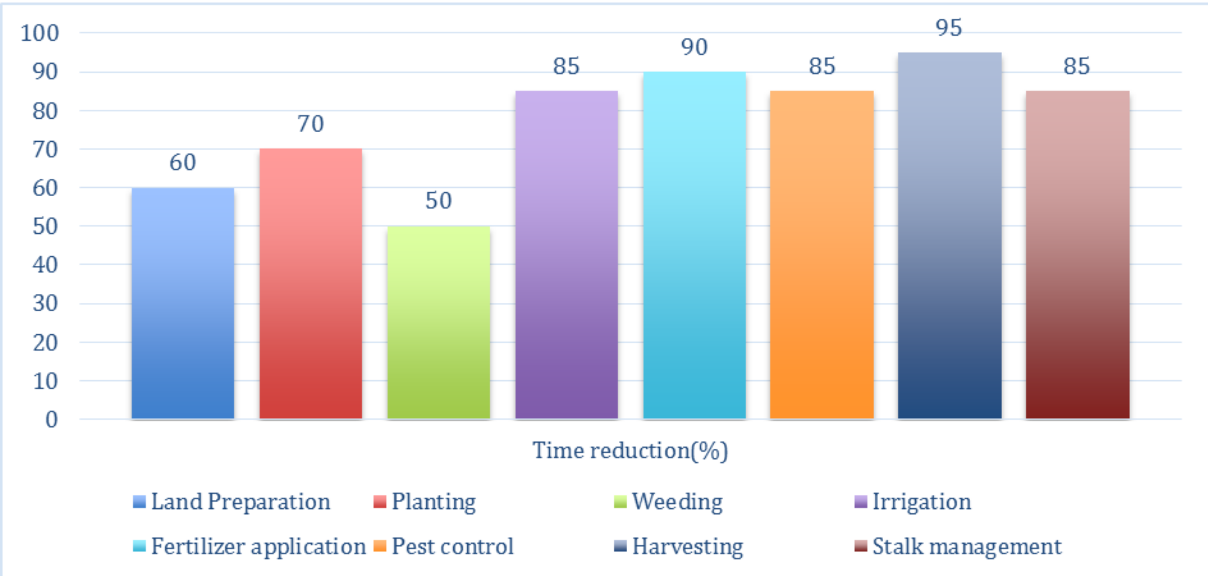


Fig 4: Time reduction for operations in mechanized to conventional cultivation

Table 10. Cost in various farm operations in Conventionalvs Mechanized HDPS

Operation	Conventional	Cost of operation (Rs) / ha	Mechanized HDPS	Cost of operation Rs / ha
Cost of Field Preparation	Desi plough	12500	Ploughing &Rotavator	9250
Cost of seed	Desi BT	6250	RASI Swift (RCH-971)	12000
Seed Packets Used	03	-	06	-
Spacing	90x45	-	90x15	-
Fertilizer Cost	RDF (N:P:K)	12500	RDF (N:P:K)	10000

Cost of Seed cum Fertilizer Sowing	Manual sowing behind plough Dibbling or Seed dropping	10000	Pneumatic planter sowing	8500
Cost of Weeding	Manual weeding	12500	Tractor mounted weeder	10500
Flowering and Boll bursting	Non-synchronized in flowering and boll bursting	-	Synchronized flowering and uniform boll bursting	-
Cost of Spraying application	Power Sprayer/ knapsack sprayer	8750	Tractor-operated Boom Sprayer/Drone Sprayer	7500
Cost of Cotton Picking	Manual Picking	12500	Battery-operated Cotton Picker	10000
Fibre Quality	Normal	-	Good	-
Pheromone traps/ Yellow sticky traps	Not generally preferred	0	4 traps/acre	1250
Crop Period	Long duration (180 days)	-	Short duration (130-140 days)	
Cost of Shredder	Manual picking and burning	0	Machine Shredding the crop stalk	5000
Total yields (q/ha)	90×45	16	90×15	28
MSP 2023-24 Per quantal	Conventional method (short-staple)	6760	HDPS method (medium staple)	6993
Total Expenditure	-	75,000	-	74,000
Gross income	-	1,08,160	-	1,95,804
Net income	-	33,160	-	1,21,804
BC ratio		1.44		2.64

CONCLUSION

The high-density planting system is considered to be the upcoming technology with the potential to fortify India's cotton economy. Widely proven in various countries, this technology may boost seed cotton productivity and mitigates risks in cotton farming. HDPS combined with appropriate genotypes, good agronomic practices, properplant protection techniques, and improved mechanization offers a promising approach to overcome stagnant yields in predominantly rainfed cotton-growing regions of India. HDPS aims to increase production by increasing plant density in the cotton cultivation per unit area from 9800 plants per acre to 29500 plants per acre exhibiting a maximum yield of 2700 – 3200 kg/ha seed cotton. The use of agricultural machinery in planting, weeding and harvesting can significantly reduce the time and labor required, cuts production cost, which is bonus for rainfed cotton farmers in particular.

The net B:C ratio for mechanized HDPS cotton cultivation was 2.64 compared to 1.44 for conventional cultivation. The mechanized HDPS cotton cultivation increases overall production process efficiency and profitability. Therefore, HDPS has been identified as a promising method to improve cotton production efficiency, especially in rainfedfarming conditions, and even to overcome irrigation constraints.

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