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Partial mechanization in BT cotton (*Gossypium hirsutum* L.) for soil sustainability under rainfed conditions

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ABSTRACT

In India, nearly 25-30 million tonnes of cotton stalks are produced annually; the majority of which is burnt in-situ. The adoption of machinery in farm operations is lagging because of various factors like unavailability of credit to purchase expensive machinery, small size holdings of farmers, and lack of technical knowledge and skills to operate complex farm machinery. A field study was conducted during kharif 2020, 2021, and 2022 on a sandy loam soil at Regional Agricultural Research Station, Palem, Nagarkurnool district, Telangana State, India in a large plot size design without replications to assess the performance of cotton under partial mechanization with two treatments i.e., T1: Farmer's practice (manual dibbling of seed/inter cultivation with cattle pair/burning of cotton residues) and T2: Partial mechanization (use of pneumatic vacuum planter/power weeder/cotton shredder). The results revealed that growth, yield attributes, and yield (6.94%) of cotton were significantly higher with partial mechanization compared to farmer's practices. Soil physical and chemical characteristics were also significantly improved under partial mechanization when compared to farmer's practices. Higher gross returns, net returns with an increase of Rs 12,536 per hectare, and the highest B:C ratio were also obtained with partial mechanization in cotton under rainfed conditions.

Keywords: *Cotton, partial mechanization, pneumatic cotton planter, power weeder, sustainability.*

INTRODUCTION

India ranks first in the world in area (12.77 million ha) and production (28.50 million bales) [22]. In Telangana State, it was cultivated in an area of 2.12 million ha during 2019-20 and it stood third in the country with a production of 55.61 million tonnes [23]. In India and Telangana, cotton crop generates nearly 25-30 MT and 4.0-5.0 MT of stalks, respectively with an average stalk production of 2-3 t ha-1 [15] and are rich in nutrients having 51.0, 4.9, 1.0, 0.61, 0.08, 0.43 and 0.12 % C, H, N, K, P, Ca and Mg, respectively [1]. The majority of the farmers resort to burning of cotton stalks in-situ to clear the field for the next crop which leads to environmental pollution through the emission of green house gases and adversely affects the soil microbial population. Open–field burning of the crop–residues is the easiest option for farmers to quickly remove the biomass and pre-pare the field for the next crop [11]. Cotton stands third (9.8) in terms of air pollution emission intensity (PM 2.5) next to sugarcane (12.0) and maize (11.2) [19]. Instead of burning, these stalks can be shredded and returned to the soil for improving the soil and crop productivity apart from using for the purpose of livestock feed, composting, biofuels (biochar and bio-oils), mulching, etc. Crop residues, whether they are incorporated into the soil or left on the surface, can have a variety of advantageous effects on the physical, chemical, and biological properties of soil.

On the other hand, lack of awareness about modern cultivation practices among Indian farmers, inefficient crop production technologies, too much dependence on labor to cultivate cotton, shortage of labor along with the associated rise in wages in some fast industrializing areas of India is impacting the profitability of the cotton crop. In many parts of India, the farmers still use human labor for many of the operations like planting, weeding, and picking and use inefficient farm implements/machinery for these operations. The adoption of machinery in farm operations is lagging because of the small size holdings of farmers, and the lack of technical knowledge and skills to operate complex farm machinery [7].

However, using sophisticated equipment like a pneumatic

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planter, power weeder, and cotton shredder can reduce the burning of cotton stalks in the field and reduce the dependency on labor for cultivating cotton. A positive balance of NH4+ - N and NO3- - N pools in cotton stalks applied plots at the end of the crop season, indicating N-mineralization [4]. Labor cost in India is rapidly increasing and therefore mechanization in cotton cultivation will play a key role in keeping the cost under control. Keeping the above aspects in view, an experiment was conducted to assess the impact of partial mechanization on growth, yield of cotton, and soil characteristics in Bt cotton under rainfed conditions.

MATERIALS AND METHODS

A field study was conducted during *Kharif* 2020, 2021, and 2022at Regional Agricultural Research Station, Palem, Nagarkurnool district, Professor Jayashankar Telangana State Agricultural University, Telangana State, India located geographically (16.30'49.8” N, 78.15'5.6” E) in Southern Telangana Zone of Telangana State. The mean weekly maximum temperatures for the cropping period ranged between 26 and 33.1°C during three years of study (Figure 1). While the minimum weekly temperature ranged from 15.3 to 25.4°C (Figure 2). Rainfall amount of 896.8, 549.1, and 725.3 mm was received during three years of cropping period with a deviation of 60%, -10%, and 23%, respectively over normal (Figure 3).

The soil of the experimental site was sandy loam in texture, moderately alkaline with respect to pH (7.24), non-saline in nature (EC-0.39 dS m^{-1}), low in organic carbon (0.33%), low in available nitrogen status (188 kg ha^{-1}), medium in available phosphorous (65 kg ha^{-1}) and high in potassium status (365 kg ha^{-1}). The statistical design of the experiment was a large plot size (1000 m^2) without replications and data recorded on growth, yield attributes were statistically analyzed with a t-test design. The treatments were T_1: Farmer's practice (manual dibbling of seed/intercultivation with cattle pair/burning of cotton residues) and T_2: Partial mechanization (use of pneumatic vacuum planter/weeder/cotton shredder). The Shaktiman pneumatic planter (SVPP -250) used in the study is a 4-4 row equipment that has a working efficiency of 2-4 acres per hour, seed carrying capacity of 140 kg, fertilizer holding capacity of 340 kg, a precise and uniform plant to plant spacing and depth for better germination, which is run with a tractor capacity of 50 HP and above. The cotton hybrid 'Sadanand' was sown at a spacing of 90 cm x 30 cm in both the treatments by manual dibbling and pneumatic cotton planter, respectively during July month of every year (15th July, 19th July and 22nd July, respectively). The recommended dose of fertilizer (120:60:60-kg ha^{-1} N; P_2O_5: K_2O) was supplied through Urea, SSP, and MOP; where an entire dose of P was applied as basal and N and K in equal splits at basal, 20, 40,60 and 80 days after sowing when there is sufficient moisture in the soil. The crop was grown under the rainfed condition without any irrigation. Intercultivation was carried out with cattle pair in farmer's practice at 30, 50, and 70 days after sowing, and the operation of the power weeder twice (at 30 and 50 days after sowing) was done in partial mechanization treatment. Picking cotton was done manually. After the final picking each year (30th November, 2nd December, and 11th December, respectively), the cotton stubbles in the farmer's practice were burned while tractor operated cotton shredder (with a shredding capacity of 500-1000 kg per hour) was used to incorporate the cotton stalks in the partial mechanization (Figure 5,6 and 7). Other agronomic management practices were carried out as per the recommendations.

Observations like plant height, monopodial branches, sympodial branches, dry matter accumulation, and yield attributes were recorded from five representative plants of each treatment. The cumulative yield of seed cotton from each picking in each treatment from the net plot was weighed in g $plot^{-1}$ and converted to kg ha^{-1}. The cotton stalk uprooted from the corresponding net plot area of treatment was sun-dried for one week and the dry weight was recorded and expressed in kg ha^{-1}. The cost of cultivation was worked out from the summation of expenditure incurred in the imposition of the treatments like land preparation, sowing, weeding, operation of implements, inputs applied and labor wages, etc in rupees per hectare. The gross returns were calculated by using prevailing market rates of cotton during the corresponding years and the net returns were obtained by subtracting the cost of cultivation from the gross returns, and the B:C ratio as the ratio of gross returns to cost of cultivation.

CHEMICAL ANALYSIS OF PLANT AND SOIL

Cotton plant samples at 90 DAS were collected and analyzed for N, P, and K contents by adopting standard procedures at the laboratory of the Regional Agricultural Research Station, (RARS), Palem (Table 1 & 2). The values of N, P, and K contents for plant samples were recorded treatment-wise, and then N, P, and K uptakes were determined for plant samples of each treatment by using the following formula.

Nutrient uptake= Content of nutrient(%) x Total dry matter production (kg ha-1)/100

Table 1. Method employed for plant analysis

S.No.	Nutrient	Method
1.	Total Nitrogen	Modified Kjeldhal"s method [8]
2.	Total Phosphorus	Di-acid digestion method and colorimetric estimation [14]
3.	Total Potassium	Di-acid digestion method followed by Flame photometer method [8]

BULK DENSITY

The bulk density of the experimental soil was estimated at 0-15cm depth by following the standard procedures given below [6].

$$\text{BD (g cc-1)} = \frac{\text{weight ofoven dry soil}}{\text{Volume ofsoil}}$$

SOIL ANALYSIS

Soil samples were drawn before sowing and at harvest and analyzed for the following parameters by standard procedures.

Table 2. The method employed for soil analysis

S.No	Parameter	Method
1.	pH (1:2.5 soil: water)	Glass electrode pH meter [8]
2.	EC (dS m^{-1}) at 25 °C (1: 2.5 soil: water suspension)	Solubridge method Method[8]
3.	Organic carbon (%)	Wet digestion method [21]
4.	Available nitrogen (kg ha^{-1})	Alkaline Potassium Permanganate Method [18]
5.	Available phosphorus (kg ha^{-1})	Olsen's extractant method [12]
6.	Available potassium (kg ha^{-1})	Neutral normal ammonium acetate method using flame photometer [8]

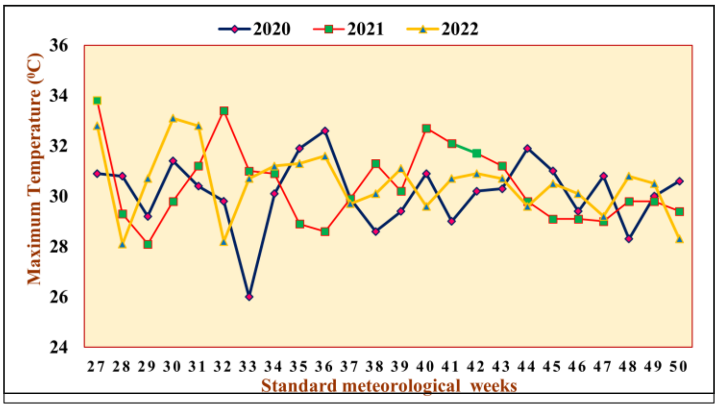

Table 1. Method employed for plant analysis

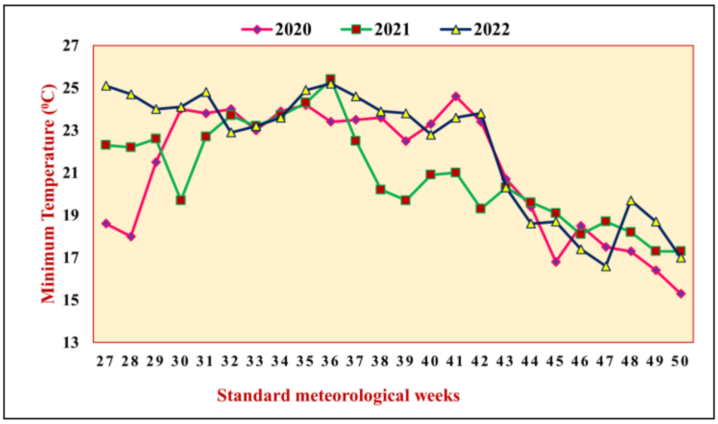

Figure 2. Weekly minimum temperature (ºC) during crop growth period

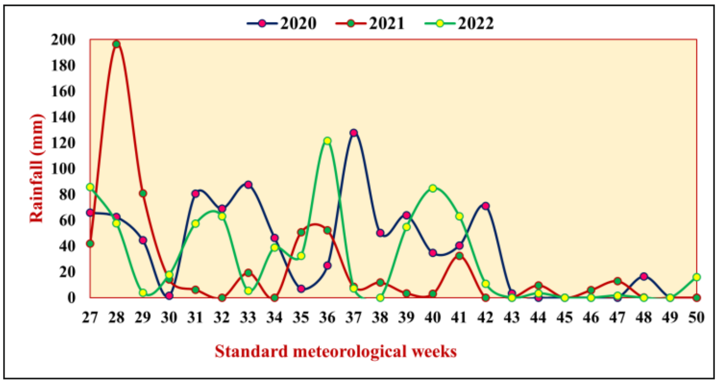

Figure 3. Weekly rainfall (mm) during crop growth period

RESULTS AND DISCUSSION

Plant height

The plant height recorded at 90 DAS was significantly higher under partial mechanization during 2021, 2022 and on the pooled mean basis (Table 3). This might be due to the addition of nutrients through cotton stalks incorporation or the increase in the availability of nutrients by complexing properties of crop residues [9].

No.of Monopodia

The number of monopodia was not significantly influenced by partial mechanization during all the years of study through a numerically higher number of monopodia was recorded with partial mechanization over farmer's practice on the pooled mean basis (Table 3).

No.of sympodia and Dry matter accumulation

The number of sympodia and dry matter was not significantly influenced by partial mechanization during 2020. However, there was a significant increase in the number under partial mechanization during 2021, and 2022 and on pooled basis over farmer's practice (Tables 3 & Figure 4). During the initial year though the cotton stalks include nutrients, they are unavailable to plants because they are organically bound and must be mineralized in order to become available. Later residues are decomposed and then mineralized after incorporation by a variety of soil microbes. As a result, the agricultural residues are physically, chemically, and physiologically digested and finally converted into the organic matter [17]. Thus the availability of nutrients to the crop will gradually increase. Crop residues also reduce the leaching loss of nutrients and evaporation loss. Thus the water and nutrients might be more available in partial mechanization plots over farmer's practice which gradually leads to an increase in the growth of the crop.

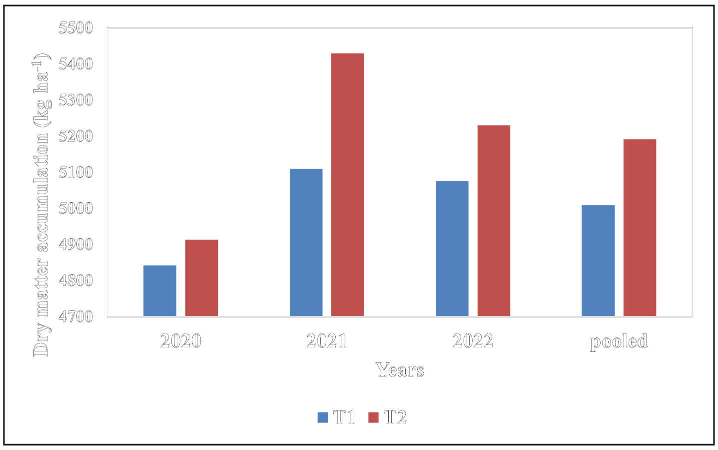

Figure 4. Dry matter accumulation (kg ha-1) in cotton as influenced by partial mechanization during kharif 2020, 2021 and 2022

Boll weight

The average boll weight of cotton was not significantly influenced by partial mechanization during all the years of study though numerically higher average boll weight was recorded with partial mechanization over farmer's practice on the pooled mean basis (Table 4). This might be due to the fact that the boll weight is the genetic character that cannot be altered easily.

Seed cotton yield and stalk yield

The seed cotton yield and stalk yield were significantly influenced by partial mechanization during 2021, 2022 and on pooled mean basis over farmer's practice (Table 4). The crop residues after decomposition produced several organic compounds and increased the availability of nutrients which resulted in the increase of seed cotton and stalk yield under partial mechanization during 2021 and 2022. An increase in the yield might also be due to the fact that the C:N ratio of cotton stalks was getting narrowed down with the advancement of time but by the end of 2nd crop season (2021). There was a positive balance of NH4 + -N and NO3- -N pools in cotton stalks applied plots at the end of the crop season indicating the N-mineralization, but it might have not been in the magnitude to effect yield enhancement in the 1st season itself [4]. However, the yield advantage due to the incorporation of residues with a wide C: N ratio was realized in 2021, and 2022 and in pooled basis.

Table 3: Growth parameters of cotton under partial mechanization during kharif 2020, 2021 and 2022

Treatment		Plant height (cm) at 90 DAS				No. of Monopodia/ plant				No. of Sympodia/ plant			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice (dibbling of seed/intercultivation/ burning of cotton residues)	111.3	104.2	110.0	108.5	1.2	2	1.4	1.5	13.6	13.4	12	13.0
T_2	Partial Mechanization (use of cotton planter /seed drill/weeder/cotton shredder)	115.6	112.0	114.0	114.2	1.2	2	1.8	1.7	14.0	14.2	13.4	13.9
P value		2.15	7.83	6.12	5.69	0.001	0.001	0.001	0.01	0.19	0.004	0.007	2.29
t-stat-value		NS	Sig.	Sig.	Sig.	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.

Table 4: Yield of cotton under partial mechanization during kharif 2020, 2021 and 2022

Treatment		Boll weight (g)				Seed cotton yield ($kg\ ha^{-1}$)				Stalk yield ($kg\ ha^{-1}$)			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice(dibbling of seed/intercultivation/burning of cotton residues)	4.70	6.0	6.0	5.6	1484	1764	1894	1714	5097	5482	5321	5300
T_2	Partial Mechanization (use of /weeder/cotton shredder)	4.78	6.2	6.2	5.7	1585	1850	2064	1833	5198	5797	5586	5527
P value		0.13	0.10	0.08	0.03	0.05	5.2	0.0001	2.12	0.11	0.01	0.004	0.002
t-stat-value		NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	NS	Sig .	Sig.	Sig.

Table 5 :pH, EC, OC and BD of the soil after harvest of cotton during kharif 2020, 2021 and 2022

Treatment		Ph				EC ($dS\ m^{-1}$)				OC (%)				Bulk density ($g\ cc^{-1}$)			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice(dibbling of seed/ intercultivation/burning of cotton residues)	7.26	7.32	7.46	7.34	0.39	0.41	0.44	0.41	0.32	0.31	0.29	0.30	1.38	1.38	1.39	1.38
T_2	Partial Mechanization (use of seed drill/weeder/cotton shredder)	7.20	7.15	7.02	7.12	0.37	0.35	0.31	0.34	0.33	0.36	0.40	0.36	1.38	1.36	1.34	1.36
P value		0.047	1.25	2.04	3.57	0.073	0.001	2.63	8.62	0.063	0.0003	7.45	0.006	0.37	0.02	0.001	2.07
t-stat-value		NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	NS	NS	Sig.	NS

Table 6 :Available nutrient status (kg ha-1) of the soil after harvest of cotton during kharif 2020, 2021 and 2022

Treatment		N ($kg\ ha^{-1}$)				P_2O_5 ($kg\ ha^{-1}$)				K_2O ($kg\ ha^{-1}$)			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice(dibbling of seed/ intercultivation/burning of cotton residues)	186	185	183	185	66	64	61	64	362	360	356	359
T_2	Partial Mechanization (use of seed drill/weeder/cotton shredder)	189	192	197	193	67	68	71	69	367	370	377	371
P value		0.016	0.001	1.23	0.001	0.12	0.001	2.93	0.0002	0.014	3.51	5.49	5.62
t-stat-value		Sig.	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 7: N, P and K uptake (kg ha-1) in cotton at 90 DAS during kharif 2020, 2021 and 2022

Treatment		N uptake (kg ha⁻¹)				P uptake (kg ha⁻¹)				K uptake (kg ha⁻¹)			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice(dibbling of seed/ intercultivation/burning of cotton residues)	67.7	66.4	65.9	65.1	19.8	21.4	20.3	20.5	111.3	112.4	111.7	110.2
T_2	Partial Mechanization (useof seed drill/weeder/cotton shredder)	73.7	86.8	88.9	83.1	22.1	26.1	26.6	24.9	112.9	130.3	130.7	124.6
P value		0.004	6.18	3.64	2.09	0.007	0.0003	1.49	0.0002	0.28	2.88	2.57	2.03
t-stat-value		NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.	NS	Sig.	Sig.	Sig.

Table 8 : Economics of cotton under partial mechanization during kharif 2020, 2021 and 2022

Treatment		Gross returns (Rs ha⁻¹)				Net Returns (Rs ha⁻¹)				B:C ratio			
		2020	2021	2022	Pooled	2020	2021	2022	Pooled	2020	2021	2022	Pooled
T_1	Farmers practice(dibbling of seed/ intercultivation/burning of cotton residues)	81219	167580	157202	135334	55569	114980	96312	88954	1.60	3.19	2.58	2.46
T_2	Partial Mechanization (use of seed drill/weeder/cotton shredder)	86747	175750	171312	144603	64897	125925	113647	101490	1.85	3.53	2.97	2.78
Market price of kapas **(Rs kg⁻¹)**		54.72	95.00	83.00									

Table 9 : Cost of Cultivation (Rs ha-1) of Bt cotton under partial mechanization (mean of 3 years)

Particulars	Farmer's Practice (Rs ha⁻¹)	Partial Mechanization (Rs ha⁻¹)	Saving (Rs ha⁻¹)
Land Preparation	3500	3000	500
Seed	4500	5400	-900
Herbicide	2100	0	2100
Pesticide	4480	4480	0
Fertilizer	7310	7310	0
Labour			
Sowing	3000	500	2500
Intercultivation	4500	3475	1025
Herbicide Application	1000	0	1000
Fertilizer Application	2500	2500	0
Pesticide Application	6000	6000	0
Picking	25000	25000	0
Total (Rs ha⁻¹)	**63890**	**57665**	**7325**

Fig 5. Precise sowing of cotton with vacuum planter

Fig 6. Uniform crop emergence with vacuum planter

Fig 7. Cotton stalks incorporation with shredderSoil pH, EC and OC

Data revealed that the soil pH, EC, and OC were significantly influenced by partial mechanization during 2021, and 2022 and on the pooled mean basis (Table 5). This might be due to the fact that the decomposition of cotton stalks by soil microbes will release the organic acids which resulted in a gradual decrease in the soil pH, EC, and increased OC under partial mechanization over farmer's practice [5] while they remained non-significant during 2020.

Bulk density

There was a significant reduction in the soil bulk density in partial mechanization in 2022 (Table 5). Reduction in bulk density might be due to the reason that the treatment receiving crop residue maintained higher organic carbon content which resulted in better aggregation and porosity [13]. However, during 2020, 2021 and on the pooled mean basis there was no significant impact of mechanization on soil bulk density.

Available soil N, P2O5 and K2O

Available soil nitrogen, phosphorous, and potassium were found significantly higher under partial mechanization when compared to the farmer's practice (Table 6). This might be due to the fact that stalk return enhances nitrogen mineralization and can activate organic phosphorus through the release of organic acids during stubble decomposition, thus increasing the availability of soil nutrients [10].

N, P, and K uptake

The N, P, and K uptake was significantly influenced by partial mechanization during 2021, 2022 and on pooled mean basis over farmer's practice (Table 7). Addition and decomposition of cotton stalks which are rich in nutrients to the soil after shredding has made more nutrients available in the root zone of the partial mechanization soil which encouraged the absorption and translocation of more nutrients resulting in higher biomass production and uptake by the crop.

Cost of cultivation

There was a reduction in the cost of cultivation to an extent of Rs 7325 ha-1 with partial mechanization (Rs.57665 ha-1) over farmer's practice (Rs. 63890 ha-1) on pooled mean basis owing to saving in labor usage for sowing, weeding and herbicide spray which are excluded in partial mechanization as observed in Table 9. These findings are in tune with [2], [3], and [16].

Gross returns

Higher gross returns (Rs. 144603 ha-1) were recorded with partial mechanization in cotton over farmer's practice (Rs. 135334 ha-1) on the pooled mean basis (Table 8). Similar results were reported by [2].

Net returns

Higher net returns (Rs 101490 ha-1) were recorded with partial mechanization in cotton over farmers' practice, (Rs 88954 ha-1) on the pooled mean basis(Table 8) with an increase of Rs 12,536 per hectare in similar lines of [2] and [20].

B:C ratio

Higher net returns (2.78) were recorded with partial mechanization in cotton over farmer's practice, (2.46) on the pooled mean basis (Table 8), also reported by [2].

CONCLUSION

From the observations of the present study, it can be concluded that partial mechanization of cotton cultivation by using a pneumatic planter for sowing, a power weeder for inter cultivation and a cotton shredder for the management of cotton residues is beneficial with an increase of 6.94 % in yield, net returns of Rs 12,536 ha-1 apart from disposing of the cotton stalk residues in a sustainable manner and improving the soil physical, chemical and biological properties.

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FUTURE SCOPE

There is a need for a package of complete mechanization in cotton through the development of mechanical harvesters which can further enhance the profitability of the farmer with timely field operations and little dependence on labor.

AUTHOR DECLARATIONS

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Conflicts of interest/Competing Interests

The authors declare no conflict of interest associated with this article.

Consent for publication

The necessary permission is taken from Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Availability of data and material/ Data availability

All data generated or analyzed during this study are included in this published article.

Author's Contribution

Conceptualization, investigation, and original draft preparation - M. Malla Reddy, K. Sridhar,; Revision of original draft –K.Avil Kumar, Ch.Damodar Raju and M.Goverdhan.; Data collection and data entry –K.Sridhar, M.Parimala Kumar and Ch.Sravan Kumar.; Statistical analysis and Tabulation –N.Lavanya, . All authors read and approved the final manuscript.

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