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Enhancing sustainability and productivity in upland rice-okra-green manure cropping systems through conservation agriculture practices

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Abstract
Conservation agriculture (CA) is a sustainable farming approach aimed at enhancing agricultural productivity while minimizing environmental impact. It is based on three core principles: minimal soil disturbance, permanent soil cover, and diversified crop rotations. This study explores the application of CA practices in upland rice-based cropping systems to improve productivity and sustainability. A field experiment was conducted from 2019 to 2021 at Kerala Agricultural University's Agronomy Farm to evaluate environmentally friendly conservation measures for upland rice-based cropping systems. The study compared a rice-okra-green manure cropping system under conservation practices with conventional methods, employing ten treatments with three replications. The first rice crop was established using two planting methods—flatbed and raised bed—in combination with either green manuring or brown manuring. Following rice cultivation, okra was grown with minimal soil disturbance, and cowpea was introduced as a green manure crop in the third phase over two years. Pooled results from the two-year experiment indicated that direct-seeded rice in a flatbed with green manuring achieved the highest grain yield (2.71 t/ha), crop water use efficiency (10.77 kg/ha-mm), field water use efficiency (1.33 kg/ha-mm), relative economic efficiency (11.08), and partial factor productivity for nitrogen (92.35 kg/ha), phosphorus (87.07 kg/ha), and potassium (87.07 kg/ha). The conservation agriculture practices applied to the preceding rice and okra crops significantly influenced the growth, yield attributes, and productivity of okra within the rice-okra-green manure cropping system. Okra grown on a flatbed with crop residue mulching outperformed other treatments, yielding a maximum productivity of 16.47 t/ha under the direct-seeded rice in a flatbed with green manuring, followed by okra with crop residue mulch. Resource use efficiency parameters, including crop water use efficiency and partial factor productivity, were highest under direct-seeded rice in a flatbed with green manuring, followed by okra with crop residue mulch. These results were statistically on par with direct-seeded rice in a flatbed with brown manuring, followed by okra with crop residue mulch. The highest benefit-cost ratio for the entire cropping system was observed in the sequence of direct-seeded rice in a flatbed with green manuring, followed by okra with crop residue mulch and cowpea as green manure. Overall, the study concluded that adopting a system-based approach with direct-seeded rice in a flatbed with green manuring, followed by okra with crop residue mulch and cowpea as green manure, is a cost-effective, environmentally sustainable, and resource-efficient conservation agriculture practice for upland farming. This approach enhances yield, profitability, and resource use efficiency, making it a viable strategy for sustainable upland agriculture.

Keywords: Partial factor productivity, productivity, relative economic efficiency, resource use efficiency

Introduction
Indian agriculture has made significant strides in increasing food grain production. However, these gains have been accompanied by widespread resource degradation, posing a serious challenge to sustaining the capacity to meet the growing population's food demand. The research and development efforts during the Green Revolution primarily focused on enhancing the productivity of selected food grains and a few other crops, successfully achieving food security. The strategies used in the green revolution are no longer working. That is by applying the same inputs we are not getting the same output as we got earlier. This will call for new strategies which are different than the ones we adopted in the 'green revolution' era. The new challenge is to achieve nutritional security while conserving the resources and make agriculture

more profitable and competitive. Conservation Agriculture (CA) with universal principles of providing minimum soil disturbance, providing permanent soil cover (through crop residues/cover crops) and crop rotations is now considered as a principle way to achieve goals of higher productivity while protecting natural resources and environment. In CA system there is a major deviation from the past ways of doing things. Beneficial effects of CA system includes higher stable yields, income, climate change adaptation and reduced vulnerability, reduced greenhouse gas emissions, carbon sequestration, better ecosystem functioning and service with increased agro biodiversity (Kassam and Friedrich., 2009) [13]. Additionally, crop diversification plays a crucial role in weed management by reducing competition between crops and weeds for resources, thereby promoting crop growth and increasing overall system productivity (Sharma *et al*., 2021) [25]. Conservation agriculture practices directly influence resource use efficiency and yield, making them a critical agronomic strategy for addressing food security challenges. Moreover, adopting appropriate conservation practices and cropping systems enables year-round cultivation, improving farm productivity and sustainability.

Against this backdrop, the present study aims to develop and evaluate conservation agriculture practices for an upland rice–vegetable–green manure cropping system. The objective is to establish cost-effective, environmentally friendly, and resource-efficient conservation technologies for rice-based cropping systems, ensuring long-term agricultural sustainability.

Materials and Methods

Experimental site

The field experiment was conducted at the Agronomy Farm, College of Agriculture, Vellanikkara, positioned at 10° 31¹ N latitude and 76° 13¹ E longitude, spanning the period from May 2019 to March 2021. The experimental site is characterized by a tropical humid climate, with an average annual rainfall of 300 mm and maximum and minimum temperatures reaching 36°C and 21 °C, respectively.

Soil analysis

Soil samples were collected at depths of 15, 30, and 45 cm to assess pH and available organic carbon using the wet digestion method. Nitrogen, P2O5, and K2O content, soil microbial biomass, and dehydrogenase activity were determined through alkaline permanganate method, Bray's P method, ammonium acetate extractable method, fumigation extraction, and soil enzyme assays, respectively. The estimated soil values were as follows: pH 4.74, available organic carbon 1.18% (15 cm), 0.95% (30 cm), 0.70% (45 cm), nitrogen 174 kg/ha, P2O5 63 kg/ha, K2O 201 kg/ha, soil microbial biomass 75.12 µg/g soil, and dehydrogenase activity 45.50 µg TPF g^{-1} soil day^{-1}.

Crop Rotation and Layout

The cropping sequence included rice as the initial crop in May, followed by okra in September and cowpea in January. The experiment was repeated for two consecutive years with the same layout. The randomized block design was employed for the experiment, and the first rice crop (variety Vaisakh) consisted of six treatments, each replicated thrice. Treatments (T_1-T_6) included various combinations of direct seeding, bed types (flat and raised bed), and manuring practices(green manuring and brown manuring). Treatments consisted of T_1- Direct seeded rice in flat bed + Brown manuring, T_2- Direct seeded rice in flat bed + green manuring, T_3- Direct seeded rice in raised bed + brown manuring, T_4- Direct seeded rice in raised bed + green manuring, T_5- Direct seeded rice in flat bed, T_6- Direct seeded rice in raised bed. Rice seeds were planted in flat bed and raised bed. The plot size of flat bed was 5mx 4 m. And for raised beds three raised beds of 5 m x1 m x 30 cm each were taken in a plot area of 5 m x 4 m. For entire cropping system the same layout was used for raising the subsequent crops with minimum soil disturbance. Paddy seeds were dibbled @ 80 kg/ha at a spacing of 20 ×10 cm. The treatment T_1 to T_4 of rice was raised in two plots each to raise second crop okra and third crop cowpea in T_1 to T_8. The whole cropping system consisted of ten treatments. *In situ* green manuring was done by uprooting the cowpea plants at 25 DAS and placed between the paddy rows as mulch. For brown manuring, cowpea was incorporated after spraying of 2, 4- D @ 1.25 kg ha^{-1} at 25 DAS. Uniform hand weeding was done in all the plots at 30 DAS.

For raising second crop okra, *Arka Anamika*' variety of okra was used for this study. Crop residue which is left in the above ground portion after harvest of rice was cleaned by using brush cutter. Field was made weed free before sowing with minimum soil disturbance using brush cutter after harvest of rice. After rice harvest, the okra seeds at the rate of 8.5 kg/ha was dibbled in planting holes at a spacing of 60 x 30 cm without disturbing the rest of the area and earthing up was given at the time of fertilizer application with minimum disturbance by piling soil up just as a support around base of the plant. Cowpea seeds were also dibbled in alternate rows along with okra for in situ green manuring for only the treatments where green manuring is specified. The cowpea was uprooted and spread as mulch at 25 DAS in those treatments (1-1.5 t/ha). For crop residue mulching in okra, 50% straw of previous rice crop (5-6 t/ha) was retained at the time of harvest and it was cut and spread in the field using brush cutter for crop residue mulching before planting of okra. After harvest of okra, the field was cleaned by brush cutter and cowpea seeds were sowed as green manure as third crop in sequence of this cropping system. The yield, resource use efficiency and economics is detailed here

Resource use efficiency is the output of any crop or any thing else per unit of the resource applied under a specified set of soil and climatic conditions. The resource use efficiency and assessment of cropping system is calculated by following ways:-

a) Water use efficiency

How efficiently water is utilized by the crop in yield is expressed by water use efficiency. It may be described as.,

$$\text{Water use efficiency} = \frac{\text{Yield (kg/ha)}}{\text{/EVAPO transpiration (mm)}}$$

Field water use efficiency was calculated by dividing the economic crop yield by total quantity of water received (irrigation water + effective rainfall) in field and it was expressed in kg/ ha/ mm.

b) Partial factor productivity

Partial factor productivity indicates kg crop yield per kg nutrient applied, It may be expressed as, PFP= $\frac{Y}{N}$

PFP = partial factor productivity

Y= yield (kg/ha)

N= amount of nutrient applied (kg/ha)

c) Land use efficiency

Here i=1,2,3…..n

n= total number of crops
D_i = number of days occupied by i th crop

$$\text{Land use efficiency} = \frac{\sum^{n}_{(i=1)} D_i}{365} * 100$$

d) Relative economic efficiency
The economic efficiency of a new system can be assessed by relative economic efficiency. It can be determined by the following formula.

$$\text{Relative economic efficiency} = \frac{\text{Net return of the improved system} - \text{Net return of the existing system}}{\text{Net return of the existing system}}$$

Parameters for assessing cropping system
a) Crop equivalent yield (CEY)
Crop A equivalent yield of crop B

$$\text{CEY (t/ ha)} = \frac{\text{Yield of crop B (kg/ha) X Price of crop B (Rs./kg)}}{\text{Price of crop A (Rs./kg)}}$$

By this crop equivalent yield of rice and okra separately in the system was calculated.

b) Multiple cropping index

$$\text{MCI} = \frac{\sum^{n}_{i=1} a_i}{A} * 100$$

MCI = multiple cropping index
i=1,2,3….n
n= total number of crops
a_i = area occupied by the i th crop
A = total land area available for cultivated crop

Cost of cultivation was calculated by adding labour charge, input costs and treatment costs. Gross return was calculated based on the market price of crop. Prevailing price for grain and straw in the market were considered in case of rice and fruit price in case of okra. Net returns is the difference between gross returns and gross expenditure. It was expressed in Rupees/ ha. The ratio of gross return to cost of cultivation was the benefit: cost ratio.
Data pertaining to different findings were tabulated and statistically analyzed by applying the technique of analysis of variance using the WASP 2.0 package and the significance among the treatments was estimated at 5 per cent of probability (Gomez and Gomez, 1984) [9].

Results and Discussion
Conservation agriculture, with its emphasis on sustainable and resource-efficient practices, holds significant promise in enhancing agricultural productivity. This study investigates the impact of conservation agriculture practices in the context of an upland rice-okra-green manure cropping system, focusing on various aspects of resource use efficiency and yield.

Yield and water use efficiency
The adoption of conservation agriculture practices within the rice-okra-green manure cropping system has demonstrated a noteworthy impact on resource use efficiency and yield. A comparison between conservation and non-conservation treatments in rice reveals compelling results supported by relevant literature.

1. Yield Enhancement
Conservation agriculture based management practices have potential role in improving the resource use efficiency as it play a major role in sustainable agriculture production. The effect of upland rice-okra –green manure cropping system in various resource use efficiency and yield was studied on this backdrop.

Yield and water use efficiency
Conservation agriculture practices in rice-okra-green manure cropping system had significant influence in the resource use efficiency and also in yield. In rice while compare to the non conservation treatments, conservation treatments showed significant increase in yield. The pooled data of two years in rice indicated that 47.65 % increase in grain yield was recorded in rice grown in flat bed along with cowpea for green manuring than rice grown alone in flat bed (Fig-1,2,3). The data given in Table -1 clearly depicted the significant effect of conservation treatments on crop and field water use efficiency of rice. Highest crop water use efficiency was recorded in direct seeding rice in flat bed + green manuring (T_2) (10.77 kg/ha mm) and it differed significantly over other treatments. The lowest was registered in direct seeding rice in flat bed (T_5) (5.44 kg/ha mm).
Field water use efficiency of rice was found to be the highest in direct seeding rice in a flat bed with green manuring (T_2) at 1.33 kg/ha mm, followed by direct seeding rice in a flat bed with brown manuring (T_1) at 1.17 kg/ha mm. This was comparable to direct seeding rice in a raised bed with green manuring (T_4) at 1.16 kg/ha mm. The highest crop and field water use efficiency in rice were consistently recorded in direct seeding rice in a flat bed with green manuring. Conservation methods improve water use efficiency, potentially attributed to increased yield and moisture conservation, as reported by Parihar *et al*. (2017).
The intercropping of cowpea plots also displayed higher water use efficiency. Even when compared to direct seeding rice grown alone in a flatbed, the direct seeding rice grown alone in a raised bed recorded higher water use efficiency. This suggests that the modification itself, particularly the adoption of conservation practices, plays a pivotal role in improving water use efficiency.
These results align with previous studies by Das (2013) [4], Ram *et al*. (2012) [21], and Singh *et al*. (2006), emphasizing that conservation treatments, by enhancing water use efficiency (WUE), contribute to soil water conservation. This, in turn, promotes favourable conditions for growth and yield increase in rice compared to treatments without conservation practices. So in case of WUE conservation treatments helps to conserve soil water which in turn may favour the growth and yield increase in rice compared to treatments without conservation treatments. Okra was raised as succeeding crop of rice keeping the same layout. For imposing conservation treatments okra was raised without soil disturbance both in flat and raised beds. For keeping the field permanently covered, crop residue mulching and green manuring was done. These treatments were compared with okra grown in flat and raised bed thoroughly ploughed and without crop residue mulching and green manuring. From the pooled data it is revealed that 53.18 % increase in yield was recorded in

direct seeding rice in flat bed + green manuring - okra + crop residue mulch (T_4) compared to direct seeding rice in raised bed + green manuring - okra + green manuring (T_5) (Fig-4). Due to continuous cropping in same field the compactness of bed caused water deficit and reduced the water intake by the crop. So, there might be a competition between the crop and green manure for water which might have reduced the yield. Similar finding was reported by Hasanuzzaman (2019) [10].

A perusal of data on crop water use efficiency in okra (Table 2.) clearly indicated that there was a significant difference among the treatments. It was observed that direct seeding rice in flat bed + green manuring-okra + crop residue mulch (T_4) recorded significantly higher field water use efficiency (51.44 kg/ha mm) followed by direct seeding rice in flat bed + brown manuring-okra+crop residue mulch (T_2) (49.77 kg/ha mm) and they both are on par to each other. The crop water use efficiency was significantly lowest in direct seeding rice in raised bed + brown manuring - okra + green manuring (T_5) (24.10 kg/ha mm). Conservation agriculture treatments applied to previous crop and okra crop favourably increased the water use efficiency of okra. Water use efficiency in okra was highest in direct seeding rice in flat bed + green manuring-okra+crop residue mulch. Residual effect of previous crop and the mulching may conserve the moisture. The result agree with the findings of Yadav *et al*.,2020 that the residual effect of previous crop improves the water use efficiency in succeeding crop. No till and ground cover may reduce the runoff and may save the water. The presence of straw reduces the soil temperature and thereby conserves the soil moisture and it also improved the water use efficiency. This results agree with the findings of Fabrizzi *et al.*, 2005 [6], Li *et al*.,2013 that mulches act as protective cover on the surface and thereby it conserves moisture by reducing the temperature and evaporation.

Relative economic efficiency

As perusal of data (Table -1) it was found that highest relative economic efficiency with respect to the net return of the existing system was direct seeding rice in flat bed + green manuring (T_2) (11.08). The lowest relative economic efficiency of 3.30 was recorded in direct seeding rice in raised bed (T_6) compared to the existing system. Relative economic efficiency is the comparative study of net return from the improved or diversified system to the net return of the existing system. The increased relative economic efficiency was due to increased yield and return from the cowpea intercropped plot than the pure crop. Similar results were reported by Sankaranarayanan *et al.*, 2012 [24] that the additional returns from the diversified system by the yield increment thereby increase in relative economic efficiency. The data pertaining to relative economic efficiency of okra is depicted in Table 2. The highest relative economic efficiency was recorded in direct seeding rice in flat bed + green manuring-okra+crop residue mulch (T_4) (0.36). Better growth and yield parameters obtained in this treatment improved the yield and finally the net return. Similar findings were reported by Reddy and Mohammad (2009) [23] that yield increase improves the relative economic efficiency. The lowest was found in direct seeding rice in raised bed + brown manuring - okra + green manuring (T_5) (-0.62). Data on the effect of relative economic efficiency of cropping system is depicted in Table 4. The highest relative economic efficiency in whole cropping system was recorded in direct seeding rice in flat bed + green manuring-okra+crop residue mulch-. cowpea (T_4) (0.60) followed by direct seeding rice in flat bed + brown manuring- okra + crop residue mulch-cowpea (T_2) (0.50). Direct seeding rice in raised bed + brown manuring - okra + green manuring (T_5) – cowpea registered lowest relative economic efficiency of -0.48. Diversification of crop the major principle of conservation agriculture may also be a reason for the improvement of relative economic efficiency in the whole cropping system. The results are in consonance with the findings of Banjara *et al*.,2021 [2] that diversification of rice-wheat cropping system with rice-potato-green gram resulted in increase in relative economic efficiency.

Partial factor productivity (PFP)

Partial factor productivity is a useful measure which quantifies the nutrient use efficiency. Partial factor productivity of nitrogen, phosphorus and potassium were significantly influenced by different conservation practices after the experiment in both the years in rice and the data pertaining to it is furnished in Table 1. It is clear from the pooled data in that partial factor productivity of nitrogen, phosphorous and potassium were significantly higher in direct seeding rice in flat bed + green manuring(T_2) (92.35,87.07, 87.07kg/ha) respectively. Lowest partial factor productivity was noticed in direct seeding rice in flat bed (T_5) for nitrogen (46.67 kg.ha), phosphorus (44 kg/ha) and potassium (44 kg/ha).

. Partial factor productivity (PFP) of nitrogen, phosphorus and potassium were significantly higher in direct seeding rice in flat bed + green manuring and the lowest partial factor productivity was in direct seeding rice grown alone in flat bed. The higher nutrient content in system of growing green manure along with rice resulted in better growth and yield of rice over control.The highest PFP in green manure treated plots might be due to the higher yield in green manure treated plot as it is a function of yield with amount of nutrient applied. And also the increased microbial population for green manure decomposition adds the organic matter content in soil and it may help in nutrient transformation in the soil and transform the nutrients in available form which can be taken up by the plants and may improve the yield and thereby improves the PFP. The results agree with the findings of Amanullah and Almas (2009) [1] that the increased microbial decomposition made the nutrients readily available to plant and improves the nutrient use efficiency. The less partial factor productivity in non-conservation methods may be due to reduced yield in this treatments.

Data pertaining to partial factor productivity of nitrogen phosphorus and potassium of okra are furnished in Table 2. From the table it was observed that the highest partial factor productivity of nitrogen (164.74 kg/ha), phosphorus(470.69 kg/ha) and potassium(235.35 kg.ha) was recorded in direct seeding rice in flat bed + green manuring-okra+crop residue mulch (T_4) it was on par with direct seeding rice in flat bed + brown manuring- okra + crop residue mulch (T_2).Direct seeding rice in raised bed + brown manuring - okra + green manuring (T_5) recorded lowest partial factor productivity for nitrogen, phosphorus and potassium (77.12, 220.34, 110.17 kg/ha respectively). In general the partial factor productivity was higher in mulched plot of okra. Similar findings were reported by Choudhary and Behera (2019) [3] that crop residue mulching improved the nitrogen economy and improved the nitrogen use efficiency. Rahmann *et al*.,2005 also reported a largest apparent recovery of nitrogen was under mulch treated plots than no mulch treatments. Similar results were also reported by Deep *et al*.,2019 [5]. In addition to this mulching effect the residual effect of previous crop may improve the nutrition status of soil and thereby it improves the nutritional supply to succeeding crop. This results were in conformity with the findings of Gill *et al*.,2020 that green manuring is one of the best alternative to improve the soil health and meet the nutritional requirement of succeeding crop. The beneficial effects of conservation agriculture treatments applied to previous crop and okra resulted in better growth and yield of okra. The increased partial factor productivity of all the nutrients in conservation agriculture treatments may be due to this yield increase and better utilization of nutrients.

Biomass and dry matter yield of green manure cowpea

Cowpea was raised as green manure crop in the sequence.Conservation treatments applied to previous crop significantly influenced the growth performance of cowpea grown as third crop. The increase in biomass yield helped to add more organic matter by incorporation of green manure and it had added advantage in the conservation agriculture practice based cropping system. From the pooled data the highest biomass and drymatter yield was recorded by treatments with rice in flat bed + green manuring - okra + crop residue mulch-cowpea (1920.22 kg/ha.,576.07 kg/ha) followed by direct seeding rice in flat bed + brown manuring - okra + crop residue mulch-cowpea (1799.11 kg/ha, 539.73 kg/ha) (Table-3).A substantial build up of soil fertility by preceding crops in the cropping system might be the reason for increased biomass and dry matter yield in cowpea.

Similar findings were reported by Mishra and Giri,2004 that the yield of succeding crop improved by the nutrient contribution and built up of fertility by the preceding crop. The crop residue mulching in okra also causes a substantial improvement in soil fertility.Hemalatha *et al*.,2000 reported that the decomposition of crop residue in turn maintain the soil available nitrogen status and thereby improves the crop growth.The lowest biomass and dry matter yield was registered in direct seeding rice in raised bed + brown manuring - okra + green manuring-cowpea. In general, performance of crops in raised beds was less except rice. As there was no disturbance of soil after harvest of rice and okra beds may get compacted. Due to this compaction proper penetration of roots may not happen and it may resulted in less nutrient supply to plants for gowth. This result is in conformity with the findings of Ghani *et al*., 2007 [7] that beds prepared manually than with proper machinery causes compaction easily and while considering a whole cropping system the same raised bed may not be effective for all crops due to this reason.

Resource use efficiency of system Land use efficiency

The land use efficiency of whole cropping system was depicted in Table 4. From the table it's clearly indicated that for all the conservation treatments (T_1-T_8) the land use efficiency was 72.60 and for other two treatments *ie* direct seeding rice in flat bed –okra –fallow (T_9) and direct seeding rice in raised bed – okra- fallow (T_{10}) the land use efficiency was 60.27. Effectiveness of land use by better utilization of available land is required for sustainable agricultural production. Here all conservation treatments recorded 72.60% land use efficiency and the non-conservation treatments the land was kept fallow for the third season due to this the efficiency was dropped down to 60.27%. To improve the land use efficiency better utilization of fallow lands is required. Similar findings were reported by Kustysheva *et al*.,2018 [10] that as the land resources are limited the effective utilization of land is required for improving the land use efficiency and thereby to improve the yield for feeding the nation.

Assessment of cropping system

For assessing the cropping system the crop equivalent yield of rice, crop equivalent of okra and multiple cropping index are calculated and it is furnished in Table-4.

Crop equivalent yield

Details of crop equivalent yield of rice, okra as influenced by conservation treatments showed significant difference among each other and are given in Table 4.49-4.50.

Data on total rice equivalent yield of whole cropping systems are presented in Table 4. Direct seeding rice in flat bed + green manuring-okra+crop residue mulch-cowpea (T_4) produced significantly higher rice equivalent yield (24.36 t/ha) followed by direct seeding rice in flat bed + brown manuring - okra + crop residue mulch (T_2) (23.32 t/ha). Direct seeding rice in raised bed + brown manuring - okra + green manuring (T_5) registered lowest rice equivalent yield of 12.22. The data on okra equivalent yield is presented in Table 4. It was observed that direct seeding rice in flat bed + green manuring-okra+crop residue mulch (T_4) recorded significantly higher crop equivalent yield of 18.84 t/ha and it was significantly superior to all other treatments followed by direct seeding rice in flat bed + brown manuring - okra + crop residue mulch (T_2) (17.99 t/ha) and it was on par with direct seeding rice in flat bed + green manuring - okra + green manuring (T_3) (17.3 t/ha 6). Higher production potential and better market price of okra along with higher grain yield of preceding rice crops were responsible for attaining maximum rice and okra equivalent yield. The results were in conformity with the findings of Rajanand, 2018 that the higher yield of rice due to the application of liquid organic manures in previous seasons enhanced the rice equivalent yield of the system.

Direct seeding rice in flat bed + brown manuring - okra + cropresidue mulch was the next best system with significantly higher rice and okra equivalent yield. Similar findings were reported by Kumari *et al*.,2020 the higher rice equivalent yield was reported in the cropping sequence were yield and there by net returns are high. Even though all conservation treatments had better performance in rice the yield decrement in second crop okra is the reason for reduction of equivalent yield in raised beds as it lost the beneficial rotational impact.

Multiple cropping index

Data on the effect of conservation treatments on multiple cropping index was furnished in Table - 4.51. Multiple cropping index of whole cropping system ranged from 280—300 %. The conservation treatments (T_1-T_8) recorded 300 % multiple cropping index and non-conservation treatments (T_9-T_{10}) registered 280 % multiple cropping index. In the present investigation, crop diversification (Rice-okra-cowpea) resulted in higher multiple cropping index of 300 % from the system over the control rice-okra-fallow (200%). Better utilization of fallow lands improves the multiple cropping index. Intensification of the system with diversified cropping increased the intensity of operations, availability of nutrients on the same piece of land and crop productivity (Prasad *et al*.,2013) [19].

Economics

Data pertaining to the cost of cultivation, gross return, net return and B:C ratio of different cropping sequences are furnished in Table 3. Direct seeding rice in flat bed +green manuring-okra + crop residue mulch-cowpea (T_4) gave the highest gross return and net return of Rs. 718508/- and Rs. 502013/- respectively. While direct seeding rice in raised bed+brown manuring - okra+green manuring-cowpea (T_5) had the lowest gross return (Rs. 377829/-) and net return (Rs.166659/-). The highest B:C ratio of 3.31 was recorded in direct seeding rice in flat bed

+green manuring-okra + crop residue mulch-cowpea (T_4) followed by direct seeding rice in flat bed + brown manuring-okra + crop residue mulch-cowpea (T_2) of 3.16. B:C ratio was found to be the lowest (1.78) for direct seeding rice in raised bed+ brown manuring-okra+green manuring-cowpea (T_5). Economic analysis of the total system revealed the profitability of conservation practices. Among the different treatments, direct seeding rice in flat bed +green manuring- okra + crop residue mulch-cowpea proved its distinct superiority over the rest of the treatments. This was mainly due to higher production potential of this cropping sequence. Direct seeding rice in flat bed + brown manuring-okra + crop residue mulch-cowpea was the next best cropping system to provide higher net profit due and B:C ratio. Higher yield and lower cost of cultivation by incorporation of a cereal-vegetable and green manure cropping system improves the B:C ratio. Similar result was reported by Shrikant *et al*.,2011 [26] that from various rice based cropping system the rice-vegetable-green manure cropping system provides high net returns and high B:C ratio. Similar findings were reported by Kachroo *et al*.,2012 [12] that diversification of crops improves the net return. The reduction in B:C ratio in raised beds is due to the yield decrement of okra which in turn leads to less net return.

Table 1: Effect of conservation agriculture practices on resource use efficiency of rice (pooled data)

Treatments	Crop water use efficiency (kg/ha mm)	Field water use efficiency (kg/ha mm)	Relative economic efficiency	Partial factor productvity (N) kg/ha	Partial factor productvity (P) kg/ha	Partial factor productvity (K) kg/ha
T_1-Direct seeding rice in flat bed + Brown manuring	9.48^b	1.17^b	9.50	81.29^b	76.64^b	76.64^b
T_2-Direct seeding rice in flat bed + Green manuring	10.77^a	1.33^a	11.08	92.35^a	87.07^a	87.07^a
T_3-Direct seeding rice in raised bed + Brown manuring	7.89^c	0.98^c	5.79	67.68^c	63.81^c	63.81^c
T_4- Direct seeding rice in raised bed + Green manuring	9.36^b	1.16^b	8.83	80.23^b	75.64^b	75.64^b
T_5- Direct seeding rice in flat bed	5.44^d	0.67^d	-	46.67^d	44.00^d	44.00^d
T_6- Direct seeding rice in raised bed	7.05^c	0.87^c	3.30	60.51^c	57.05^c	57.05^c
Sem	0.31	0.04	9.50	2.64	2.49	2.49
CD(0.05)	0.92	0.11	11.08	7.93	7.47	7.47

Table 2: Effect of conservation agriculture practices on resource use efficiency of okra (pooled data)

Treatments	Crop water use efficiency (kg/ha mm)	Relative economic efficiency	Partial factor productvity (N) kg/ha	Partial factor productvity (P) kg/ha	Partial factor productvity (K) kg/ha
T_1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring	45.55^{bc}	0.13	145.48^{bc}	415.65^{bc}	207.82^{bc}
T_2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch	49.77^a	0.29	159.10^a	454.57^a	227.29^a
T_3-Direct seeding rice in flat bed + Green manuring - okra + green manuring	46.88^b	0.19	149.94^b	428.41^b	214.20^b
T_4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch	51.44^a	0.36	164.74^a	470.69^a	235.35^a
T_5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring	24.10^g	-0.62	77.12^g	220.34^g	110.17^g
T_6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch	31.72^e	-0.34	101.56^e	290.16^e	145.08^e
T_7-Direct seeding rice in raised bed + Green manuring - okra + green manuring	27.68^f	-0.48	88.99^f	254.27^f	127.13^f
T_8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch	35.46^d	-0.21	113.16^d	323.30^d	161.65^d
T_9-Direct seeding rice in flat bed – okra	44.16^c	-	141.06^c	403.04^c	201.52^c
T_{10}-Direct seeding rice in raised bed – okra	33.94^d	-0.29	108.60^d	310.27^d	155.14^d
SEm	0.67	0.13	2.11	6.02	3.01
CD(0.05)	2.01	0.29	6.32	18.05	9.03

Table 3: Effect of conservation agriculture practices on resource use efficiency of whole system (pooled data)

Treatments	Land use efficiency (kg/ha mm)	Relative economic efficiency	Rice equivalent yield (t/ha)	Okra equivalent yield (t/ha)	Multiple cropping index
T_1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	72.60	0.34	21.57[c]	16.63[c]	300
T_2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	72.60	0.50	23.32[b]	17.99[b]	300
T_3-Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	72.60	0.43	22.48[b]	17.36[b]	300
T_4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	72.60	0.60	24.36[a]	18.84[a]	300
T_5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	72.60	-0.48	12.22[h]	9.44[h]	300
T_6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	72.60	-0.20	15.38[f]	11.88[f]	300
T_7-Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	72.60	-0.27	14.10[g]	10.96[g]	300
T_8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	72.60	-0.01	17.36[e]	13.38[e]	300
T_9-Direct seeding rice in flat bed – okra-fallow	60.27	-	19.86[d]	15.29[d]	280
T_{10}-Direct seeding rice in raised bed – okra-fallow	60.27	-0.20	16.06[f]	12.39[f]	280
SEm	-	-	1.33	0.22	-
CD(0.05)	-	-	0.90	0.68	-

Table 4: Effect of conservation agriculture practices on green manure yield and economics of whole cropping system

Treatments	Biomass yield (kg/ha)	Dry matter yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1- Direct seeding rice in flat bed + Brown manuring - okra+ green manuring -cowpea	1465.56[b]	439.67[b]	217801	640774	422973	2.93
T_2-Direct seeding rice in flat bed + Brown manuring - okra + crop residue mulch -cowpea	1799.11[a]	539.73[a]	217131	687898	470767	3.16
T_3-Direct seeding rice in flat bed + Green manuring - okra + green manuring -cowpea	1468.22[b]	440.47[b]	216941	667818	450877	3.07
T_4-Direct seeding rice in flat bed + Green manuring - okra + crop residue mulch -cowpea	1920.22[a]	576.07[a]	216496	718508	502013	3.31
T_5-Direct seeding rice in raised bed + Brown manuring - okra + green manuring -cowpea	855.56[e]	256.67[e]	210631	377289	166659	1.78
T_6-Direct seeding rice in raised bed + Brown manuring -okra+ crop residue mulch-cowpea	1034.44[de]	310.33[de]	208631	462445	253814	2.21
T_7-Direct seeding rice in raised bed + Green manuring - okra + green manuring -cowpea	1167.78[cd]	350.33[cd]	207285	435404	228119	2.10
T_8-Direct seeding rice in raised bed + Green manuring - okra+ crop residue mulch -cowpea	1236.11[c]	370.83[c]	209885	523427	313542	2.48
T_9-Direct seeding rice in flat bed – okra-fallow	-	-	256061	576668	320607	2.24
T_{10}-Direct seeding rice in raised bed – okra-fallow	-	-	221911	478132	256220	2.15
SEm	60.47	18.14	-	-	-	-
CD(0.05)	181.41	54.42	-	-	-	-

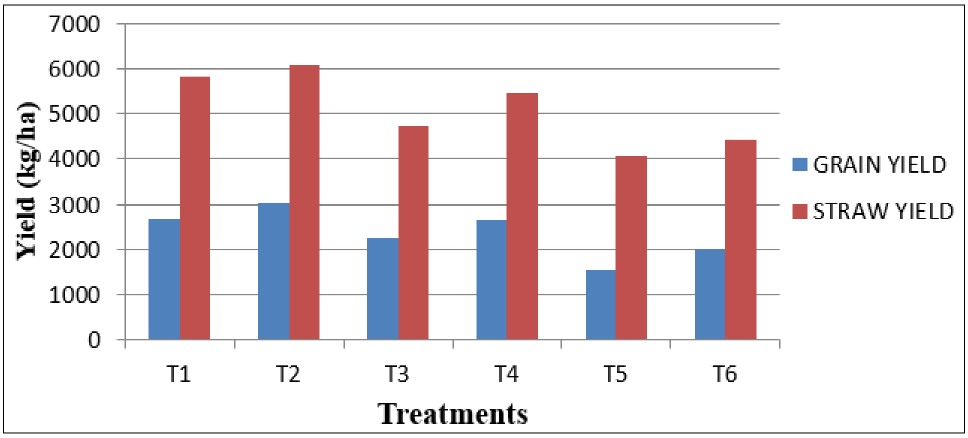

Fig 1: Grain yield and straw yield of rice as affected by conservation treatments

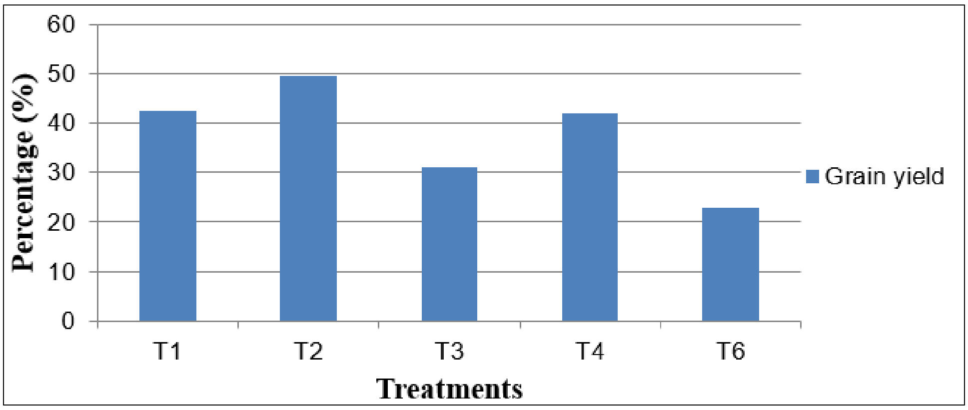

Fig 2: Percentage increase in grain yield in conservation agriculture system

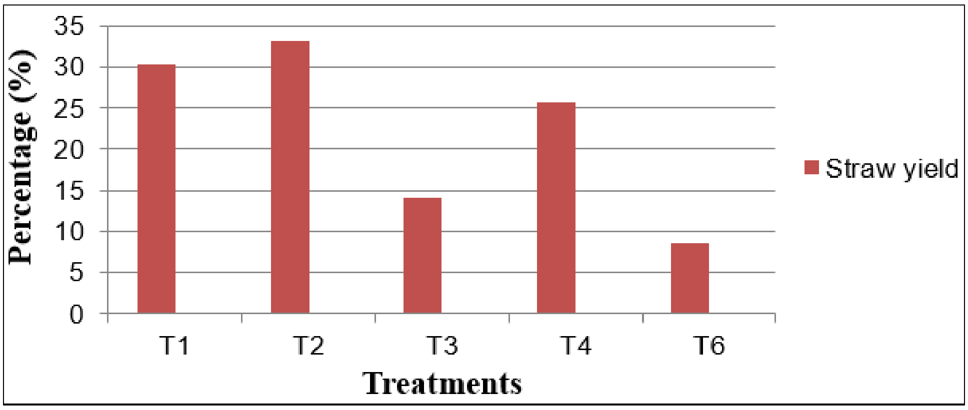

Fig 3: Percentage increase in straw yield in conservation agriculture system

T_1-DSR in FB +BM; T_2-DSR in FB +GM; T_3-DSR in RB +BM; T_4-DSR in RB + GM; T_5- DSR in FB; T_6- DSR in RB.

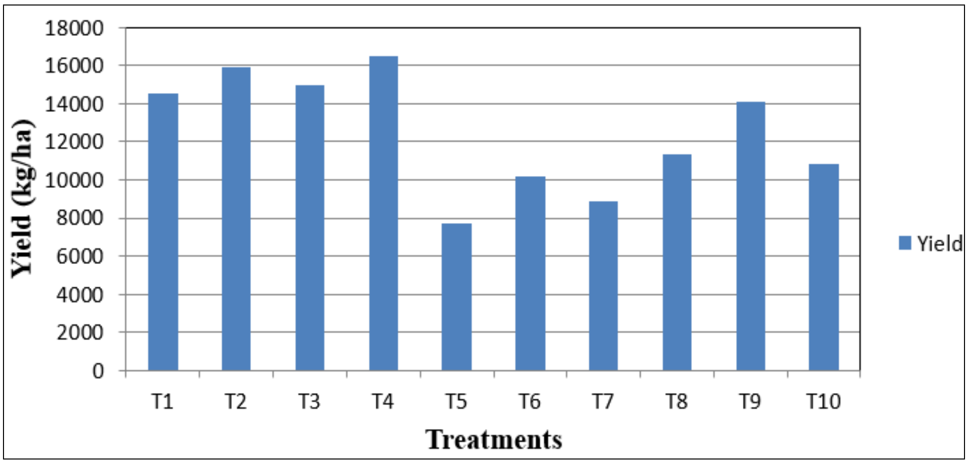

Fig 4: Effect of conservation treatments on yield (kg/ha) of okra

T_1- DSR in FB +BM-okra+GM; T_2-DSR in FB+ BM- okra + CRM; T_3-DSR in FB+ GM- okra + GM; T_4-DSR in FB+ GM- okra + CRM; T_5-DSR in RB+ BM- okra + GM; T_6-DSR in RB+ BM-okra+ CRM; T_7-DSR in RB+ GM- okra + GM; T_8-DSR in RB+ GM- okra+ CRM; T_9-DSR in flat bed – okra; T_{10}-DSR in raised bed – okra

Conclusion

From the above results it can be concluded that the system of growing direct seeding rice in flat bed with either green manuring or brown manuring followed by okra with crop residue mulch followed by green manure cowpea can be recommended as an economically viable practice for upland rice-vegetable-green manure cropping system as it increases the profitability.

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