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Conservation agriculture practices: Impact on productivity, energy utilisation and profitability of onion-based cropping system

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Abstract

A field experiment was conducted to evaluate the performance of onion based cropping system under conservation agriculture (CA) and conventional tillage (CT) practice on the system productivity, production efficiency and energy use. It was conducted for two years during 2019-20 and 2020-21 at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India. The experiment was laid out in a split plot design with three replications. The main plot consists of four cropping systems viz., CA - Onion - Foxtail millet (C₁), CA - Onion - Barnyard millet (C₂), CT - Onion - Foxtail millet (C₃), CT - Onion - Barnyard millet (C₄), Onion - Sole cropping (C₅) and sub plot consists of foliar application of three organics. Foliar application of organics includes, 3% Panchagavya (F₁), 1% PPFM (F₂), and 0.1% Humic acid (F₃). System productivity in terms of Onion equivalent yield (OEY) was significantly higher (9042kg ha⁻¹) in the CA - Onion - Barnyard millet cropping system with the foliar application of PPFM 1% than that of conventional method and sole cropping of onion. Resource use efficiency on the basis of productivity was higher under sole cropping of onion (86.33kg ha⁻¹ day⁻¹). CA - Onion - Barnyard millet recorded the highest energy use efficiency (1.6%) and energy productivity (0.35kg MJ⁻¹) which shows that maximum energy was effectively utilized under the system. Thus, the conservation tillage based Onion-Barnyard millet system recorded more system productivity, highest resource use efficiency (land use efficiency) and the highest energy use efficiency.

Keywords: Conservation agriculture, double cropping, system productivity and energy use

Introduction

Farmers prefer to cultivate Onion as a single crop in a year even though there is scope for raising a subsequent/successive crop. They leave the field as fallow after harvesting the first crop of onion. This can be changed by developing the suitable cultivation practices to raise a second crop after the harvest of onion. This is possible through following Conservation agriculture (CA) practices which facilitates the farmers to go for two crops in a year. Onion based millet cropping system is one of the best alternative to onion monoculture which helps to increase the year round production and maintains the sustainability. Conservation agriculture (CA), an agricultural production system with optimum inputs, high returns and sustainability while conserving environment is primarily required for command areas and rainfed uplands. CA helps to improve and conserve soil health through crop rotation, mulching, minimum field traffic and mechanical soil disturbance and conserve water to achieve economically and ecologically sustainable crop production (Swaminathan *et al.*, 2021; Selvakumar and Sivakumar, 2021) [11, 9].

Allium has almost 500 species in the 57 genera of angiosperms and largest genus in the Amaryllidaceae. Most of *Allium* species are native to the Northern Hemisphere, mainly in Asia. Onion (*Allium cepa*) has cylindrical to ovoid or rounded bulbs with coats papery and looks in white to brownish or reddish colour (Huxley *et al.*, 1992) [11]. It is one of the important bulbous and cash crop which is mostly grown in India. It is used in preparation of various food items and culinary purposes. India is the largest producer and exporter of onion than other vegetables in the world (Ramachandrappa *et al.*, 2017) [7]. Besides, it is also used as medicine for the treatment of various diseases in different parts of the world (Shaheen *et al.*, 2007) [10]. Nutritionally onion contains 1.6 KJg⁻¹ energy, carbohydrates 10%, fats 0.1%, protein 1%, water 89% and considerable amount on vitamins and minerals. The recent pandemic has pushed people to use more onions in the diet.

At the time of harvesting the whole onion plant was uprooted from the field to separate the bulb (economic part) from the plant, which resulted in removal of above and below ground

biomass that leads to reduction of soil organic carbon. Though uprooting of onion plant loosens the surface soil, still farmers go for two to three ploughing to cultivate the succeeding crops which may leads to increase in cost of cultivation (Jain *et al.*, 2021) [2]. Growing nutri-cereals such as foxtail millet and barnyard millet after harvesting of onion would provide conservation of all the available resources.

Further, cultivation of foxtail millet and barnyard millet with CA practices will reduce cost of cultivation and gives higher yield than conventionally grown these crops. With this backdrop, the study has been designed with the objective of identifying onion based cropping system under CA practices to utilize soil disturbance for harvesting onion by narrowing down the time taken to cultivate the successive crops and to assess the system productivity and energy conservation in comparison to existing conventional cultivation practices.

Materials And Method

Experimental Site characteristics

A field experiment was conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural College and Research Institute, Madurai, India during 2019-21. The experimental site is geographically located at 9° 54' N latitude and 78° 80' E longitude at an altitude of 147 m above mean sea level. The meteorological parameters averaged over 25 years revealed that a mean annual rainfall of 850 mm was received in 46 rainy days. Out of which, 39.8 per cent was distributed during South West Monsoon (SWM), 42.0 per cent during North East Monsoon (NEM), 2.1 per cent during winter and 16.1 per cent during summer. The daily mean maximum and minimum temperatures were 33.7 and 23.8°C, respectively. The mean daily pan evaporation was 6.2 mm with a mean relative humidity of 81 per cent.

Experimental details of CA practices

The experiment was laid out in a split plot design with three replications. The main plot consist of four cropping system and sub plot consists of foliar application of three organics. Cropping system includes, CA - Onion - Foxtail millet (C₁), CA - Onion - Barnyard millet (C₂), CT - Onion - Foxtail millet (C₃), CT - Onion - Barnyard millet (C₄), Onion - Sole cropping (C₅). Foliar application of organics includes 3% Panchagavya (F₁), 1% PPFM (F₂), and 0.1% humic acid (F₃).

Cultivation details Cropping sequence

Cropping sequence followed in this cropping system which means that sowing of the subsequent crop immediately after the harvest of first crop

Conservation tillage (Zero-till) Cropping sequence

The successive crops are sown immediately at the time of harvest of first crop without ploughing i.e. under no / zero tillage and cultivated. Harvesting of preceding crop and sowing of succeeding crop was done instantaneously.

Onion-Foxtail millet or Barnyard millet

Onion is harvested by pulling out the whole plant by using hand with sufficient soil moisture. At the time of pulling out of onion plants, the soil is disturbed and gets opened. Uprooting of onion plant loosens the surface soil to a depth of 5-10 cm which has been effectively utilized. Seeds of subsequent crops namely Foxtail millet and Barnyard millet were sown in soil openings made by pulling out onion plants.

Conventional tillage (Zero-till) Cropping sequence

The successive crops were sown after the harvest of first crop with required field preparation like ploughing etc. Harvesting of preceding crop and sowing of succeeding crop was not done instantly.

Conventional tillage practice

All the three crops tested were grown in separate plots and were cultivated as per the standard recommendation given in crop production guide of the State Government. The test varieties of Onion, Foxtail millet and Barnyard millet were CO 4 (65–70 days), Co (Te) 7 (85-90 days) and MDU 1 (100 days) respectively. The Onion was sown with a seed rate of 1000 kg ha⁻¹ bulblets and the fertilizer was applied at 60:60:30 NPK kg ha⁻¹. Foxtail millet and Barnyard millet were sown with a seed rate of 10 kg ha⁻¹. The recommended doses of fertilizer for Foxtail millet and Barnyard millet were 44:22 NP kg ha⁻¹ and 40:30:50 NPK kg ha⁻¹ respectively.

Specific characteristic of CO 4

It is a hybrid derivative of the cross AC 863 x CO 3 and resistant to thrips. The crop duration is 65-70 days. It yields 12-16 t/ha. The leaves are light green, erect and cylindrical. The number of bulbs per plant varies from 8 to 13 with an average weight of 90 g per clump. Bulbs are attractive light pink bold in size with good consumer appeal. The bulbs store well over 150 days (Saraswathi *et al.*, 2017) [8].

System indices

System productivity

The system level productivity of different cropping systems was estimated on Onion equivalent basis in which the economic yield of Foxtail millet and Barnyard millet were converted into Onion equivalent yield (OEY) (kg ha⁻¹) based on prevailed market price at the time of harvest. It was calculated by using the formula as follows,

$$\text{OEY (of a crop)} = Y_x (P_x) / P_j$$

Where, Y_x is the yield of crop x (kg ha⁻¹), P_x is the price of crop x, and P_j is the price of Onion.

Resource use efficiency

Resource use efficiency of the system was calculated in terms of land use efficiency (LUE). It was calculated from total duration of crop in a cropping system divided by 365, production efficiency in terms of kg ha⁻¹ day⁻¹ and was calculated by dividing total economic yield (OEY) by total duration of the crop in a cropping system.

Energy Auditing

The study also aimed to evaluate and compare the energy parameters used in Conservation (CA) and conventional (CT) based practices. The various sources of energy in cultivation of crops were computed based on the input requirements and their corresponding energy coefficient. All the inputs in the form of the labour, diesel, seed, chemicals and fertilizers were taken into consideration with the use of energy conversion factor the input energy was calculated.

The different field operations carried out in the cultivation of crops were measured in terms of time taken for humans, machinery and fuel consumption and expressed as input energy in Mega Joule (MJ).

The energy formulas pertaining to agriculture are listed below

$$1. \text{ Energy use efficiency (\%)} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}} \times 100$$

$$2. \text{ Energy productivity (kg/MJ)} = \frac{\text{Grain yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

Mittal and Dhawan, (1988) [4]

Result and Discussion

System productivity

Productivity is the ratio between the amounts of output produced to the amount of input supplied. The adoption of different cropping systems significantly influenced the productivity of onion (Table 1). The cropping system, Onion – Foxtail millet under conservation agriculture (CA) with foliar application of PPFM 1% recorded the highest onion productivity (8333kg ha⁻¹) than the conventional tillage (CT). This is because of the improvements in soil biochemical properties made due to conservation agriculture practices (Jain *et al.*, 2021) [2]. The lowest onion yield (5002kg ha⁻¹) was recorded in Onion grown as sole crop, with the foliar application of 0.1% Humic acid.

System productivity in terms of Onion equivalent yield (OEY) was significantly higher (10,252kg ha⁻¹) in the Onion – Barnyard millet cropping system under CA with the foliar application of PPFM 1% than that of CT (Table 2). The higher productivity of Onion and barnyard millet in Onion – Barnyard millet system under the CA and a stable market price for the produces during the study period favoured higher OEY. Moreover, onion increases soil aeration at the time of harvesting (uprooting) which eventually increases growth and development of the successive crop, Barnyard millet and resulted in increased yield. A similar trend has been reported in Jute-Rice-Potato system (Kumar *et al.*, 2014) [5] and Jute-Potato systems (Mandal *et al.*, 1981) [3]. The cultivation of Onion in sole cropping system (single crop per year) recorded the lowest yield (5002kg ha⁻¹), compared to the double cropping system (Two crops per year) under both CA and CT. In single cropping system, there is no successive crop and hence considered as zero yield (No crop) in calculations, that may be the reason for low equivalent yield in the Onion sole cropping, resulting into the lowest OEY of the system.

Resource use efficiency

It is expressed in terms of land use efficiency and production efficiency (Table 2). The land use efficiency was higher under Onion–Barnyard millet cropping system (46.6%) under both CA and CT. The reasons behind this was the maximum land area occupied by the two crops grown in a year in double cropping and also because of its maximum crop duration compared to sole cropping system (19.2%).

The significantly higher production efficiency was recorded in Onion sole cropping with the foliar application of 1%

PPFM (86.33kg ha⁻¹ day⁻¹). The next best treatment was Onion – Foxtail millet system under conservation tillage (CA) with the foliar application of 1% PPFM (62.66kg ha⁻¹ day⁻¹). This indicates the production efficiency of single crop in a unit land area, however, it failed to impact system productivity. This might be due to improvement in soil biochemical properties with conservation agriculture practices (Jain *et al.*, 2021) [2]. The lower production efficiency was recorded in Onion – Foxtail millet system under conventional tillage (CT) with the foliar application of 0.1% Humic acid (40.69kg ha⁻¹ day⁻¹). This might be due to the lesser productivity per duration of the cropping system.

Energy analysis

The input and output energy relationship in different onion based cropping system was calculated and presented in Table 3. While comparing the systems practices, CA based cropping system required lower energy than the CT based cropping system because energy requirement for field preparation to raise the second crop was zero and also saving of one irrigation i.e. sowing irrigation. The energy consumption through fuel, water, and machinery was also reduced under CA. Similar findings were reported by Nandan *et al.*, (2021) [6]. The highest input energy (26878MJ ha⁻¹) was given in the CT - Onion - Barnyard millet cropping system. This might be due to the greater requirements of inputs and practices like field preparation and number of irrigations barnyard millet. However, the least input energy (21956MJ ha⁻¹) was recorded in the onion sole cropping, because the other systems had two crops in a years, naturally the input requirement is low for single crop cultivation than raising more than one crop in any type of farming. Further, in the energy analysis, input energy required from sowing to harvest of barnyard millet or finger millet was totally nil or zero in single cropping where onion alone was cultivated, which ultimately resulted in lowest energy requirement.

Among the different cropping system practiced, the maximum output energy per hectare was obtained under CA based Onion - Barnyard millet system (41721 MJ ha⁻¹) which was followed by the CA based Onion - Foxtail millet (39783MJ ha⁻¹). The cultivation of double crops (Onion – Foxtail/Barnyard millet) per annum rather than going for single crop (Onion alone) had increased the output energy of the system. Accordingly, adoption of CA practices have drastically increased the overall output energy of the onion based cropping system (Nandan *et al.*, 2021; Swaminathan *et al.*, 2020) [6, 12].

CA practices based cropping system confirmed the highest energy use efficiency and energy productivity rather than the CT method and sole cropping of onion. CA based Onion-Barnyard millet system had the greatest energy use efficiency (1.6%) and energy productivity (0.35kg MJ⁻¹) while the least energy use efficiency (0.6%) and energy productivity (0.25kg MJ⁻¹) were recorded in the onion sole cropping.

Table 1: Yield of individual crops in different Onion based cropping system (kg ha⁻¹)

Treatment	Onion yield (kg ha ⁻¹)				Foxtail millet/ Barnyard millet yield (kg ha ⁻¹)			
	F ₁	F ₂	F ₃	Mean	F ₁	F ₂	F ₃	Mean
C ₁ - CA - Onion - Foxtail millet	7639	8333	5903	7292	1475	1692	1083	1417
C ₂ - CA - Onion - Barnyard millet	6475	7250	5812	6512	1694	2001	1364	1686
C ₃ - CT - Onion - Foxtail millet	6358	7014	5539	6304	1318	1430	972	1240
C ₄ - CT - Onion - Barnyard millet	6115	6952	5408	6158	1427	1652	1038	1372
C ₅ - Onion - Sole cropping	5317	6043	5002	5454	-	-	-	-

F₁ –3%Panchagavya, F₂ – 1% PPFM and F₃ – 0.1% Humic acid

Table 2: System productivity - Onion Equivalent yield (OEY), Production efficiency (kg ha⁻¹ day⁻¹) and Land use efficiency (%) of Onion based cropping system

Treatment	System productivity (OEY) (kg ha ⁻¹)				Production efficiency (kg ha ⁻¹ day ⁻¹)				Total duration of the system (Days)	Land use efficiency (%)
	F ₁	F ₂	F ₃	Mean	F ₁	F ₂	F ₃	Mean		
C ₁ - CA - Onion - Foxtail millet	9114	10025	6986	8708	56.96	62.66	43.66	54.43	160	43.8
C ₂ - CA - Onion - Barnyard millet	9016	10252	7858	9042	53.04	60.30	46.22	53.19	170	46.6
C ₃ - CT - Onion - Foxtail millet	7676	8444	6511	7544	47.98	52.78	40.69	47.15	160	43.8
C ₄ - CT - Onion - Barnyard millet	8256	9430	6965	8217	48.56	55.47	40.97	48.33	170	46.6
C ₅ - Onion - Sole cropping	5317	6043	5002	5454	75.96	86.33	71.46	77.91	70	19.2
CD (p=0.05)					538					
S.Ed					257.1					

F₁ –3%Panchagavya, F₂ - 1% PPFM and F₃ - 0.1% humic acid

Table 3: Energy analysis in different Onion based cropping system

Treatment	Energy Input (MJ/ha)	Energy Output (MJ/ha)	System Yield (kg/ha)	Energy Use Efficiency (%)	Energy Productivity (kg/MJ)
C ₁ - CA - Onion - Foxtail millet	25934	39783	8708	1.5	0.34
C ₂ - CA - Onion - Barnyard millet	26115	41721	9042	1.6	0.35
C ₃ - CT - Onion - Foxtail millet	26696	34618	7544	1.3	0.28
C ₄ - CT - Onion - Barnyard millet	26878	36185	8217	1.3	0.31
C ₅ - Onion - Sole cropping	21956	14180	5454	0.6	0.25

Conclusion

From the above results, compared to single crop onion per year, double crops (Onion-Foxtail/ Barnyard millet) along with conservation agricultural (CA) practices recorded the highest system productivity, highest land use efficiency. Resource use efficiency on the basis of productivity was higher under sole cropping of onion. The highest energy use efficiency and energy productivity also recorded in conservation agriculture (CA) based Onion-Foxtail/ Barnyard millet system. It may be concluded from the research that, cultivating the Onion followed by Foxtail millet or Barnyard millet cropping system (Double cropping) along with proper conservation agricultural practices would help to enhances the overall system productivity, resource use efficiency and minimizes the energy usage, there by helping the saving energy in crop production.

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