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**Research Paper**

# Evaluation of food and fodder based cropping systems for sustaining productivity, resource use efficiency and profitability in western plain zone of Uttar Pradesh

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## ABSTRACT

A field experiment was conducted during 2015–16 to 2018–19 at the research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, Uttar Pradesh to assess the potential yield (PY), sustainability and resource use efficiency (RUE) of 7 cropping systems (CS), viz. maize + blackgram–pea–sorghum; cluster bean-wheat-teosinte; stylo-berseem-maize + cowpea; clitoria-mustard–greengram; rice–chickpea–okra; rice–wheat and sugarcane–wheat system. The experiment was laid out in randomized block design (RBD) with 3 replications. Among the different cropping systems, rice (*Oryza sativa* L.)–chickpea (*Cicer arietinum* L.)–okra (*Abelmoschus esculentus* L.) was found to be most superior in terms of wheat equivalent yield (WEY) (19.77 t/ha/year) and sustainable yield index (SYI=0.894). The highest land use efficiency (LUE) was recorded with cluster bean (C*yamopsis tetragonoloba* L.)–wheat (*Triticum aestivum* L.)–teosinte (*Zea* spp.) cropping system (95.16%) with 347 days of ground cover. Production efficiency was registered maximum with maize (*Zea mays* L.) + blackgram [*Vigna mungo* (L.) Hepper]–pea (*Pisum sativum* L.)–sorghum [*Sorghum bicolor* (L.) Moench] system (66.91 kg/ha/day), followed by rice–chickpea–okra system (62.25 kg/ha/day). Nevertheless, the highest net return (₹ 300.8×$10^3$/year) was realized with rice–chickpea–okra system. Total soil organic carbon (SOC) content was highest (1.34%) under stylo-berseem- maize + cowpea [*Vigna unguiculata* (L.) Walp.] cropping system in comparison to other cropping systems. Thus, it can be concluded that rice–chickpea–okra system proved more productive, remunerative (₹ 824/ha/day) and sustainable cropping system than the existing sugarcane (*Saccharum officinarum* L.)–wheat/ rice–wheat cropping system in the western plain zone of Uttar Pradesh, India.

***Key words*:** Crop diversification, Resource use efficiency, Sustainable yield index, Wheat equivalent yield

Crop diversification is a strategy to increase output on the same cultivable land while cultivating various crops from decreasing land resources. Often, it can mean adding extra crops to an existing rotation. Therefore, there is a huge demand for addition of fodder based alternate cropping systems on the bedrock of diversion in existing cropping systems like sugarcane (*Saccharum officinarum* L.)–wheat (T*riticum aestivum*) and rice (*Oryza sativa* L.)–wheat in western plain zone of Uttar Pradesh. Apart from this food and fodder based cropping systems when diversified with numerous crops at single time have a win-win situation by providing wider range of benefits to producers, consumers and environment (Honnali and Chittapur, 2014). Hence, farmers should emigrate over to favourite for raising more crops on the same piece of land owing to attains multiple demands of households as well as livestock. In addition to this, diversification of crops is aimed at reducing risk and vagaries due to climatic change and variability they are prevailing in the zone. Further, it was emphasized that high-remunerative crops and cropping systems should be included in the ecosystem services (ES), they shall be supplemented and eventually displaced synthetic external inputs and resulting in maintaining productivity for a longer period of time. Indeed, diversification in existing cropping systems would be more responsive to maintaining better soil health which leads to increased nutritional security for human beings and livestock. Thus, we will be able to identify suitable food and fodder based systems for the extensive group of marginal farmers (67%) in India (Bhargavi *et al.,* 2019). Therefore, with this aim the present study was planned to develop suitable alternate

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cropping systems in place of prevailing systems which could realize higher production, enhance resources used and be economically viable for the farmers of western plain zone of Uttar Pradesh.

## MATERIALS AND METHODS

A field experiment was conducted during 2015–16 to 2018–19 at the research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, (29°04'38.8"N, 77°42'09.9"E, 237 m amsl), Uttar Pradesh which is classified as sub-tropical zone. During the experimentation (2015–16 to 2018–19) mean maximum temperatures varied from 30.4°C, 31.2°C, 30.7°C and 30.8°C and minimum temperatures 17.6°C, 17.3°C, 17.83°C and 18.1°C, respectively. The total annual rainfall at the experimentation periods (2015–16 to 2018–19) was received 710 mm, 665 mm, 736 mm and 790 mm, respectively, more than 80% of which was received through the south-west monsoon during July to September. Prior to the study, the soil was sampled from the entire experimental field at 0–30 cm depth and analyzed subsequently after making a composite sample. The initial study site was categorized as sandy loam soil having *p*H 7.99. The total soil organic carbon (SOC) was 0.89% (CHNS analyzer). Available N (176.6 kg/ha) was estimated by alkaline permanganate (KMnO4) method. Similarly, available soil P (29.3 kg/ha) was analyzed by (Jackson's, 1973) method and available soil K (194.7 kg/ha) was estimated by $NH_4OAc$ method. The 7 cropping systems, viz. maize (*Zea mays* L.) + blackgram [*Vigna mungo* (L.) Hepper]–pea (*Pisum sativum* L.) (vegetable)–sorghum [*Sorghum bicolor* (L.) Moench] (Fodder); cluster bean (*Cyamopsis tetragonoloba* L.)–wheat (*Triticum aestivum* L.)–teosinte (*Zea* spp.); stylo–berseem–maize + cowpea [*Vigna unguiculata* (L.) Walp.]; clitoria (Fodder)-mustard [*Brassica juncea* (L.) Czern.]-greengram [*Vigna radiata* (L.) R. Wilczek]; rice (*Oryza sativa* L.)-chickpea (*Cicer arietinum* L.)–okra (*Abelmoschus esculentus* L.); rice–wheat and sugarcane (*Saccharum officinarum* L.)–wheat were comprised. The net plot size of each treatment was 10 × 10 $m^2$. The experiment was laid out in randomized block design (RBD) and replicated thrice for 4 consecutive years (2015–16 to 2018–19) to identify most suitable cropping system through inclusion of pulses, cereals, oilseed, fodder, vegetable and cash crop (sugarcane) in the existing cropping systems. The details of varieties used, seed rate, spacing and fertilizer doses are given in Table 1. The sources of nutrients were urea, di-ammonium phosphate (DAP) and murate of potash (MOP)

**Table 1.** Production technologies for various crops in diversified cropping systems in western plain zone of Uttar Pradesh

| Cropping system | Season | Cultivation practices | | | |
|---|---|---|---|---|---|
| | | Crop/variety | Seed rate (kg/ha) | Spacing (cm) | Fertilizer (kg/ha) $N-P_2O_5-K_2O$ |
| Maize + blackgram-pea-sorghum | *Kharif* | Maize/Dhaval<br>Blackgram/Pant Urd-31 | 40-Maize<br>20-Blackgram | 70 × 25-Maize<br>45 × 15-Blackgram | 120:60:40-Maize<br>25:50:25-Blackgram |
| | *Rabi* | Pea/Arkel | 75 | 30 × 10 | 50:70:70 |
| | *Summer* | Sorghum/Kanpuri Safed | 40 | 25 × 10 | 80:40:30 |
| Cluster bean-wheat-teosinte | *Kharif* | Cluster bean/RGC1002 | 20 | 40 × 10 | 20:50:30 |
| | *Rabi* | Wheat/DBW-16 | 80 | 22.5 × 5 | 120:60:60 |
| | *Summer* | Teosinte/TLI | 20 | 30 × 10 | 60:30:30 |
| Stylo-berseem-maize + cowpea | *Kharif* | Stylo/Phule Kranti | 10 | 30 × 10 | 30:60:20 |
| | *Rabi* | Berseem/Mescavi | 25 | Broad Casted | 20:80:60 |
| | *Summer* | Maize/K125<br>Cowpea/EC4216 | 60 (25) | 30 × 15 Maize<br>40 × 10 cowpea | 120:80:40-Maize<br>20:60:40-Cowpea |
| Clitoria-mustard-greengram | *Kharif* | Clitoria/IGFRI-23-1 | 20 | 40 × 15 | 20:50:30 |
| | *Rabi* | Mustard/RH749 | 5 | 30 × 15 | 80:40:40 |
| | *Summer* | Greengram/SML668 | 20 | 45 × 30 | 25:50:25 |
| Rice-chickpea-okra | *Kharif* | Rice/PB1121 | 25 | 20 × 10<br>(2–3 seedlings/hill) | 120:60:60 |
| | *Rabi* | Chickpea/Avrodhi | 75 | 30 × 10 | 25:60:30 |
| | *Summer* | Okra, Arkak, Anamica | | 60 × 30 | 75:50:60 |
| Rice-wheat | *Kharif* | Rice/PB 1121 | 25 | 20 × 10<br>(2–3 seedlings/hill) | 120:60:60 |
| | *Rabi* | Wheat/DBW16 | 100 | 22.5 × 5 | 120:60:60 |
| | *Summer* | - | - | - | - |
| Sugarcane-wheat | *Kharif* | Sugarcane/Co0238 | 7000 setts | 90 × 30 (3 buds/set) | 150:60:60 |
| | *Rabi* | Wheat/ PBW226 | 100 | 22.5 × 5 | 120:60:60 |
| | *Summer* | - | - | - | - |

as per the recommended doses of respective crops. A uniform application of FYM (farmyard manure) @ 10 t/ha was applied during rainy (*kharif*) season only under all treatments because highly nutrients exhaustive triple crops were grown in quick succession round the year. The economic yield of component crops was converted into wheat equivalent yield (WEY), taking into account the prevailing farm gate price (₹/kg) of different crops. Production efficiency was deliberated as the ratio of kg (WEY/ha) to the total crop duration of the system in days. The productivity of different cropping systems was compared by calculating their economic wheat equivalent yield (WEY) as :

$$\text{WEY} = \frac{\text{Yield of each crop (kg/ha)} \times \text{Economic value of respective crop (₹/kg)}}{\text{Price of wheat grain (₹/kg)}}$$

The sustainable yield index (SYI) of the system was calculated based on the data from 4 years of system productivity as (Wanjari *et al*., 2004):

$$\text{Sustainable yield index} = \frac{\bar{Y} - \sigma}{\text{Y Max}}$$

where $\bar{Y}$, estimated mean yield; $\sigma$, estimated standard deviation; Y Max, observed maximum yield in the experiment over the years.

## RESULTS AND DISCUSSION

### *Cropping systems extent*

Among the different cropping systems, the short-duration crops, viz. pea (85 days), okra (90 days), and the cereal crops like sorghum, maize, rice, and wheat were mellowed approximately in 90, 105, 115 and 140 days, respectively. Similarly, fodder crops like cluster bean (115 days), stylo (102 days), clitoria (105 days), berseem (115 days), sorghum (90 days), teosinte ( 95 days), cowpea (105 days) were being matured at different period of times. The short-duration oilseed crop like mustard needed 115 days for maturity and pulse crops like greengram (85 days) and blackgram (115 days) took less time than other crops in various cropping systems. However, sugarcane crop required a longer growing period as compared to all other crops which were undertaken. But the cluster bean-wheat-teosinte cropping system had higher land use efficiency (95.16%) and followed by rice–chickpea–okra system (89.77%). The highest crops stand in the field was cluster bean–wheat–teosinte (347 days) and the next was sugarcane–wheat (329 days). Hence, selection of crops and their respective varieties plays pivotal role in the synergism among themselves toward efficient utilization of precious resources in order to increase overall productivity, profitability and environmental resilience (Verma *et al*., 2016).

### *System productivity*

The pooled data for 4 years related to system productivity indicated significant (P≤0.05) variation among the different cropping systems. A highly productive and efficient cropping system was sugarcane–wheat (79.65 t/ha/year) compared to other cropping systems (CS). This is mainly because of higher production potential and remunerative price of sugarcane based cropping system as reported by Kumar *et al.,* (2021) and followed by maize+blackgram-pea-sorghum (68.97 t/ha/year), while the minimum system productivity was recorded in rice–chickpea–okra (13.04 t/ha/year) in terms of economic values (Table 2). Main and byproduct yields were varied under different cropping systems. But byproducts yield was higher in the case of fodder based system i.e. maize + blackgram–pea–sorghum as compared to other cropping systems in terms of dry matter (DM) production and followed by rice–wheat system (11.60 t/ha/year) and least with clitoria–mustard–greengram system (5.53 t/ha/year). Crop equivalent yield (CEY) is an important index for assessing performance of different crops under specified conditions. Cropping systems differed considerably (P ≤0.05) with respect to wheat equivalent yield. Wheat equivalent yield (WEY) at various cropping systems was increased significantly and maximum was estimated under rice–chickpea–okra system (19.77 t/ha/year). This might be owing to better production efficiency of these crops than other crops and the next best cropping system in terms of wheat equivalent yield was maize + blackgram–pea–sorghum (18.16 t/ha/year). This might be owing to synergistic effect of crops on each other in the newly developed cropping systems. At the same time, the minimum wheat equivalent yield was obtained in stylo–berseem–maize + cowpea system (14.11 t/ha/year). The fodder crops generally had lower market worth as compared to other crops undertaken in the study. The decreasing trend of WEY was noticed in prominent prevailing cropping systems (rice–wheat and sugarcane–wheat) because economic and ecological illnesses were observed higher in these systems. Therefore, other novel cropping systems have to be identified as suggested by Singh *et al.*, (2012). These results are in line with the outcomes of Singh and Kumar (2014).

### *Land use efficiency (LEU)*

Intensification in sequential multiple cropping systems (MCS) by introduction of non-conventional/short-duration crop cultivars and intense input management is a common way to increase LUE, especially in irrigated agroecosystems. The LEU was observed to vary from 68.95 to 95.16% under different cropping systems. However, the highest LEU was attributed to the cluster bean- wheat-teosinte cropping system (95.16%) followed by rice–

**Table 2.** Effect of cropping systems on system efficiency, productivity and wheat equivalent yield (mean data of 4 years)

| Cropping system | Crop season | Crop duration (days) | System efficiency | | System productivity | | Wheat equivalent yield (t/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Land use efficiency (%) | Duration of the system (days) | Economic yield (t/ha) | By-product yield (t/ha) | 2015–16 | 2016–17 | 2017–18 | 2018–19 | Mean |
| Maize + black gram | *Kharif* | 105-Maize | 76.16 | 278 | 6.87-Maize | 7.22-Maize | | | | | |
| (BG as intercrop) – | | 105- BG | | | 0.62-BG | 1.24-BG | | | | | |
| pea–sorghum | *Rabi* | 85-Pea | | | 3.67 | 3.84 | 16.73 | 17.38 | 18.38 | 20.17 | 18.16 |
| | *Summer* | 90-Sorghum | | | 57.81 (GF) | | | | | | |
| Cluster bean– | *Kharif* | 115-Cluster bean | 96.16 | 347 | 2.94 | 3.53 | 15.92 | 16.36 | 15.04 | 15.43 | 15.68 |
| wheat–teosinte | *Rabi* | 140-Wheat | | | 4.85 | 5.60 | | | | | |
| | *Summer* | 95-Teosinte | | | 33.44 | | | | | | |
| Stylo–berseem– | *Kharif* | 102-Stylo | 87.85 | 319 | 15.23 | | 13.94 | 14.45 | 14.14 | 13.92 | 14.11 |
| maize + cowpea | *Rabi* | 115-Berseem | | | 64.79 | | | | | | |
| (as Mixed crop) | *Summer* | 105-Maize | | | 15.23 (GF) | | | | | | |
| | | 105-Cowpea | | | | | | | | | |
| Clitoria–mustard– | *Kharif* | 105-Clitoria | 86.96 | 322 | 44.45 | | 14.73 | 14.84 | 14.65 | 16.55 | 15.19 |
| green gram | *Rabi* | 115-Mustard | | | 2.81 | 3.56 | | | | | |
| | *Summer* | 85-Green gram | | | 1.35 | 1.97 | | | | | |
| Rice–chickpea– | *Kharif* | 115-Rice | 89.77 | 328 | 5.54 | 6.01 | 17.84 | 18.40 | 20.40 | 22.45 | 19.77 |
| okra | *Rabi* | 125-Chickpea | | | 1.96 | 2.53 | | | | | |
| | *Summer* | 90-Okra | | | 5.54 | 2.41 | | | | | |
| Rice–wheat | *Kharif* | 115-Rice | 68.95 | 252 | 5.65 | 6.05 | 13.94 | 14.03 | 14.08 | 14.60 | 14.16 |
| | *Rabi* | 140-Wheat | | | 4.77 | 5.55 | | | | | |
| | *Summer* | - | | | - | - | | | | | |
| Sugarcane–wheat | *Kharif* | 310-Sugarcane | 89.77 | 329 | 75.01 | 2.51 | 15.86 | 16.79 | 16.58 | 16.11 | 16.34 |
| | *Rabi* | 140-Wheat | | | 4.64 | 5.36 | | | | | |
| Statistical analysis | SEm± | | | | | | 0.57 | 0.61 | 0.77 | 1.01 | 1.13 |
| | CD (P=0.05) | | | | | 1.85 | 1.94 | 2.40 | 3.43 | 3.54 | |

BG, Blackgram; F, Fodder

chickpea–okra (89.77%) and sugarcane–wheat cropping system (89.77%) also, while the lowest was revealed in the case of rice-wheat system (68.95%). This was because of utilization of land for less duration in a year (252 days) and grown of 2 crops in a year and for the remaining period field was kept fallow (Table 2). These results were in conformity with the findings of Prasad *et al.,* (2013), who reported that intensification of rice based cropping sequence by greengram recorded markedly higher land use efficiency than normal cropping sequences that were undertaken and those without summer greengram. In multiple cropping, using short-duration crop cultivars with better management is a common way to increase LUE as also reported by Tetarwar *et al.*, (2023).

### *Sustainability*

Rice–chickpea–orka cropping system (CS) articulated the highest sustainable yield index (SYI) of 0.894 (Table 3), this might be owing to higher production potential of these crops as well as greater perceptible market worth as compared to other ones which were undertaken in the enduring cropping systems during their respective growing seasons (*kharif*, *rabi* and summer). The next most superior cropping system (CS) in terms of SYI was maize+ balckgram–pea–sorghum (0.812), while the least SYI was noticed with the stylo–berseem–maize + cowpea (0.607) and very closed SYI was seen in case of rice–wheat system (0.610). This might be due to both these cropping systems have been produced lower biomass and their market prices being cheaper than other produced commodities. Similar results were also reported by Singh *et al*., (2011) and Kumar *et al.,* (2014) in food-fodder based cropping systems.

### *Nutrient dynamics*

In general, fodder crops removed higher amounts of plant nutrients from the soil as compared to other crops grown in the different cropping systems because they produced higher tonnages of green biomass. The nutrient (NPK) uptake by the crops in various cropping systems was influenced significantly. Whereas, maximum N and P uptake (273.49 and 87.61 kg/ha) were estimated under clitoria–mustard–greengram sequence as compared to other systems (Table 3). However, the highest uptake of K by crops was realized in the rice–chickpea–okra system (433.03 kg/ha), while the negative trend was observed in sugarcane–wheat system (68.50, 46.28 and 174.25 kg/ha). A total sum of 299.25 and 182.94% higher turnover of N and P nutrients was observed under clitoria-mustard-greengram system as compared to sugarcane–wheat system. This could be possible due to mineralization of available soil nutrients being observed higher where enormous leguminous crops were integrated with other crops like wheat, maize, rice, sorghum etc.

### *Resource use efficiency*

Resource use efficiency (RUE) derives an indication of ability of plant to convert utilization of resources to economic production under certain conditions. In the present study, monetary returns efficiency (MRE) was highest in case of rice–chickpea–okra system (₹824/ha/day) followed by maize + blackgram-pea-sorghum system (₹694/ha/day) and lowest monetary return efficiency was observed with the sugarcane–wheat system (₹540 ha/day). This could be owing to longer crop duration of sugarcane in the illustrated system, which fell in line with the findings of Jat *et al.,* (2011). The maximum and minimum production efficiency (PE) was found in maize + blackgram–pea–sorghum and stylo–berseem–maize + cowpea system (44.42 kg/ha/day), respectively. Lower production efficiency of fodder-based systems was due to lower economic value of fodder resulted into lower wheat equivalent yield (WEY t/ha) than other cropping systems (Kumar and Faruqui, 2009).

### *Economic analysis*

The cost of cultivation of crops was highest in case of sugarcane–wheat system (₹132 × $10^3$/ha) and followed by maize + blackgram–pea–sorghum (₹131.7 × $10^3$/ha) (Table 3). Among the different systems, rice–chickpea–okra recorded the highest net return (₹300.8 × $10^3$/ha). Whereas, inclusion of vegetables (okra and pea), pulses (chickpea, blackgram and greengram) and major cash crop (sugarcane) in the cropping systems, surged higher in productivity and fetched more market prices, thereby, increased in net monetary returns. The lowest net monetary return (₹197.1 × $10^3$/ha) was accrued with sugarcane-wheat system because of high input demands compared with other cropping systems.

### *Soil fertility build-up*

Soil chemical property like *pH* did not turned significantly over to potential status even after end of 4 years of experimentation conducted at the same site under different cropping systems (Table 4). The *pH* of the soil was near to neutral range of 7.55 and it was reduced under all cropping systems invariable from 7.49 to 7.74 and was within a practical range of crop production. The maximum availability of plant nutrients like N and P (211.02 and 42.82 kg/ha) was found with clitoria–mustard–greengram cropping system, but the available K (232.34 kg/ha) was higher under rice–chickpea–okra system. Whereas, legume crops

**Table 3.** Effect of cropping systems on yield sustainability, system efficiency and monetary advantage under Upper Gangetic Plain region of Uttar Pradesh (mean data of 4 years)

| Cropping system | Sustainable yield index (SYI) | Nutrient uptake (kg/ha) | | | System efficiency | | Returns in terms of monetary gain | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Production efficiency (kg/ha/day) | Monetary efficiency (kg/ha/day) | Gross return (×$10^3$ ₹/ha) | Cost of cultivation (×$10^3$ ₹/ha) | Net return (×$10^3$ ₹/ha) | Return/ invested |
| Maize + blackgram (BG)–pea–sorghum | 0.812 | 88.85 | 30.96 | 191.61 | 66.91 | 694 | 385.0 | 131.7 | 253.3 | 2.92 |
| Cluster bean–wheat–teosinte | 0.687 | 167.61 | 53.47 | 363.28 | 44.98 | 577 | 303.6 | 93.0 | 210.5 | 3.26 |
| Stylo-berseem–maize + cowpea | 0.607 | 213.67 | 79.34 | 324.03 | 44.42 | 563 | 284.1 | 78.7 | 205.4 | 3.61 |
| Clitoria–mustard–greengram | 0.662 | 273.49 | 87.61 | 411.79 | 47.67 | 602 | 299.5 | 79.7 | 219.9 | 3.76 |
| Rice–chickpea–okra | 0.894 | 203.46 | 70.89 | 433.03 | 62.25 | 824 | 411.9 | 111.1 | 300.8 | 3.71 |
| Rice–wheat | 0.610 | 140.83 | 49.31 | 308.58 | 56.23 | 575 | 284.7 | 74.7 | 209.9 | 3.81 |
| Sugarcane–wheat | 0.720 | 68.50 | 46.28 | 174.25 | 50.12 | 540 | 329.8 | 132.7 | 197.1 | 2.48 |
| SEm± | | 3.23 | 2.24 | 17.95 | - | - | 5.97 | - | - | - |
| CD (P=0.05) | | 10.07 | 7.00 | 55.93 | - | - | 18.59 | - | - | - |

**Table 4.** Effect of diversified cropping systems on physico-chemical properties of the soil

| Cropping system | *p*H | Organic C (%) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) |
|---|---|---|---|---|---|
| Maize + blackgram–pea–sorghum | 7.74 | 1.007 | 187.04 | 31.90 | 209.33 |
| Cluster bean–wheat–teosinte | 7.73 | 1.064 | 201.51 | 30.91 | 223.73 |
| Stylo-berseem–maize + cowpea | 7.59 | 1.337 | 204.58 | 34.02 | 228.50 |
| Clitoria–mustard–greengram | 7.55 | 1.159 | 211.02 | 42.82 | 215.04 |
| Rice–chickpea–okra | 7.72 | 1.325 | 193.28 | 39.18 | 232.34 |
| Rice–wheat | 7.56 | 1.129 | 197.46 | 33.18 | 222.95 |
| Sugarcane–wheat | 7.49 | 0.929 | 179.37 | 30.30 | 191.00 |
| SEm± | 0.05 | 0.088 | 5.63 | 2.79 | 8.53 |
| CD (P=0.05) | 0.16 | 0.262 | 19.55 | 8.36 | 28.64 |
| Initial | 7.99 | 0.891 | 176.57 | 29.26 | 194.67 |

such as stylo–berseem–maize + cowpea had maximum positive response in tune of build-up total organic carbon (1.337%) and increased in the extend of 50.15% higher over to initial total soil organic carbon status (0.891%). The least total organic carbon (OC) strata in soil was found under the sugarcane–wheat system (0.929%) because both the crops were highly nutrients exhaustive in nature and they added meager quantity of trash and straw in the soil after their harvesting and decaying of organic matter was also power into the soil.

This study concludes that the inclusion of vegetables and pulses (rice–chickpea–okra and maize + blackgram–pea–sorghum) in the cropping systems significantly improved the system productivity and profitability along with improvement in soil health and resource use efficiency as compared to prevailing high input requiring cereal-based (rice–wheat and sugarcane–wheat) systems in western plain zone of Uttar Pradesh.

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