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Effect of Different Cropping Sequences on Soil Nutrients Status, Nutrients Uptake and Crop Yield in PAP Command Area of Tamil Nadu

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To evaluate the effect of different cropping sequences on soil nutrients status, nutrients uptake and crop yield in PAP command area an experiment was carried out at Coconut Research Station, Aliyar Nagar, Pollachi during 2017-18. In *Kharif* season, the rice crop was grown followed by seven sequential crops during *rabi* season. Thus, there were seven different cropping sequences *viz.,* Rice – Sunflower (T_1), Rice – Sesame (T_2), Rice – Blackgram (T_3), Rice – Castor (T_4), Rice – Maize (T_5), Rice – Onion (T_6) and Rice – Groundnut (T_7) cropping sequences. Results of the post - harvest soils of the different cropping sequences revealed that significantly highest soil organic carbon SOC content was observed in Rice – Groundnut (T_7) cropping sequence, however this was on par with Rice – Maize (T_5) and Rice – Castor (T_4) cropping sequences. A significant higher value of available P was registered in Rice – Blackgram (T_3) cropping sequence that was on par with Rice – Groundnut (T_7) cropping sequence. Available K was significantly higher in Rice – Groundnut (T_7) cropping sequence which was on par with Rice – Onion (T_6) cropping sequence. The Rice – Maize (T_5) cropping sequence recorded the highest total N uptake and Rice – Sunflower (T_1) cropping sequence registered higher total P uptake and the total K uptake was higher in Rice – Maize (T_5) and Rice – Sunflower (T_1) cropping sequences. Grain yield and straw yield were significantly higher under Rice – Maize (T_5) and Rice – Groundnut (T_7) cropping sequences. Though the Rice – Castor (T_4) cropping sequence recorded highest B:C ratio of 2.08, considering the quantity of water consumption, economic yield, soil nutrients and B:C ratio, the best cropping sequence registered in Parambikulam Aliyar command area was Rice – Castor (T_4) cropping sequence followed by Rice – Groundnut (T_7) and Rice – Maize (T_5) cropping sequences.

Key words: Cropping sequence, Nutrient dynamics, Nutrient uptake, Grain and Straw yield.

For the past few years, there is paucity of rains in many parts of Tamil Nadu resulting in drying of dams and reservoirs making many areas of the state drought prone including PAP command area. The Parambikulam Aliyar Project (PAP) is an interstate, multi-purpose, multi valley project, executed by Government of Tamil Nadu during 1958. The project has a cultivable command area of 1.74 lakh hectare. The Rice – Rice – Green manure cropping sequence was followed for decades and its continuous adoption may lead to deterioration of soil quality. Therefore, crop diversification is being promoted to improve the soil quality and also to achieve increased productivity with available irrigation facilities.

Considering the scarce water availability, high cost of cultivation and degrading soil quality, the existing traditional cropping sequence may not be viable in the coming years. Hence, it is the time to design a new alternate-cropping sequence in order to effectively utilize the natural resources and also to stabilize the soil quality, productivity and profitability. With this background, the field study were conducted to assess the effect of different cropping sequences on soil organic carbon, available N, P and K, nutrients uptake, yield and water consumption in PAP command area of Tamil Nadu.

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Material and Methods

Experimental site, climate and soil type

In the present investigation, field experiments were conducted during August 2017 – May 2018 (Kharif and rabi seasons) at Coconut Research Station, Aliyar Nagar, Pollachi, Coimbatore district of Tamil Nadu. The post - harvest soil samples were collected from seven cropping sequences and subjected for analysis. The soil of experimental site belongs to Aliyar soil series which is Isohyperthermic Fluventic Ustropept.

Treatment details

There were seven treatments each replicated three times in Randomized Block Design viz., Rice – Sunflower (T_1), Rice – Sesame (T_2), Rice – Black gram (T_3), Rice – Castor (T_4), Rice – Maize (T_5), Rice – Onion (T_6) and Rice – Groundnut (T_7) cropping sequences. The rice variety (CO 50) was used as a test crop in kharif season followed by other crops

in rabi season. The recommended dose of N, P_2O_5 and K_2O (kg ha^{-1}) and 12.5 tonnes of FYM were applied in rice crop – 150:50:50 in kharif season and the second season (rabi) crops also received RDF viz., Sunflower (CO_2) – 60:90:60 (kg ha^{-1}), Sesame (TMV7) – 35:23:23 (kg ha^{-1}), Black gram (ADT 5) – 25:50:25 (kg ha^{-1}), Castor (YRCH 1) – 90:45:45 (kg ha^{-1}), Maize (COH 6) – 250:75:75 (kg ha^{-1}), Onion (CO_3) – 60:60:30 (kg ha^{-1}) and Groundnut (CO 7) – 25:50:75 (kg ha^{-1}) respectively. The source of nitrogen (N), phosphorus (P) and potassium (K) were urea, Single Super Phosphate (SSP) and muriate of potash.

Analysis of soil and plant samples

A composite surface sample (0-15cm) of the experimental field was collected before the initiation of the field experiment for analysis. The characteristics of the initial surface soil are furnished in Table1. To study the chemical changes in the soil at different cropping sequences, soil samples were collected from each plot after the harvest of the kharif and rabi season crops. The soil samples collected from the field experiment was air dried, broken with wooden mallet and sieved through 2mm sieve, labelled and stored in cloth bags for further analysis. The OC was estimated by Chromic acid wet digestion (Walkley and Black, 1934), available N by alkaline permanganate method (Subbiah and Asijia, 1956), available P by extraction with 0.5M $NaHCO_3$ (Olsen, 1954) and neutral normal NH_4OAc method (Stanford and English, 1949) for available K followed by flame photometry respectively.

Besides, plant samples were analysed for N content using Di-acid extraction method (Jackson, 1973). Plant P was analysed using triple acid extract and vanadomolybdate phosphoric acid yellow colour method (Jackson, 1973) and plant K was analysed using triple acid extraction method followed by flame photometry (Piper, 1966). For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and Agres window version 7.0 packages were used.

Results and Discussion

Soil organic carbon (SOC)

The post - harvest soil of kharif season rice crop recorded the SOC content of 5.92 g kg^{-1} which was slightly higher than the initial value 5.60 g kg^{-1}. Significantly highest SOC content of 6.32 g kg^{-1} was recorded in Rice – Groundnut cropping sequence (T_7) that was on par with Rice - Castor (T_4) and Rice – Maize (T_5) cropping sequences. The mean values of post-harvest soil of different cropping sequences found an increasing trend over the post-harvest soil of rice crop. The increase in organic carbon content over the initial content was more, where FYM was applied. It was partly due to the addition of source of carbon (manure) and partly the FYM addition along with fertilizers resulted in better crop growth, which in turn resulted in addition of more plant residues in these treatments (Sharma *et al*., 2014 and Verma *et al*., 2012) (Table 2 and 3).

Table 1. Characteristics of the initial surface soil sample (0 - 15 cm) of the experimental field

Properties	Value
A. Physical properties	
Bulk density (Mg m^{-3})	1.35
Particle Density (Mg m^{-3})	2.46
Porosity (%)	45.12
Available moisture (%)	14.00
MWHC (%)	31.00
Texture	Sandy clay loam
Hydraulic Conductivity (cm hr^{-1})	1.85
Infiltration Rate (cm hr^{-1})	0.85
B. Physico - Chemical properties	
pH	8.55
EC (dS m^{-1})	0.22
CEC (C mol (p^+) kg^{-1})	17.60
C. Chemical properties	
Organic carbon (g kg^{-1})	5.60
$KMnO_4$ – N (kg ha^{-1})	270.0
Olsen – P (kg ha^{-1})	12.50
NH_4OAc – K (kg ha^{-1})	379.5

Available N

The post-harvest soil of kharif season rice crop registered available N value of 280 kg ha^{-1}. The highest available N value of 284 kg ha^{-1} was recorded in Rice – Castor cropping sequence (T_4) and the lowest was observed in Rice – Groundnut cropping sequence (T_7) with the value of 264.6 kg ha^{-1}. These small differences among the cropping sequences were statistically insignificant.

Table 2. Characteristics of the post-harvest sample (0 – 15 cm) of the rice (CO 50) experimental field in kharif season (Jun 2017 – Oct 2017)

Properties	Value
A. Physical properties	
Bulk density (Mg m^{-3})	1.33
Particle Density (Mg m^{-3})	2.46
Porosity (%)	45.96
Available moisture (%)	14.50
MWHC (%)	31.60
Texture	Sandy clay loam
Hydraulic Conductivity (cm hr^{-1})	1.87
Infiltration Rate (cm hr^{-1})	0.85
B. Physico - Chemical properties	
pH	8.50
EC (dS m^{-1})	0.29
CEC (C mol (p+) kg^{-1})	18.20
C. Chemical properties	
Organic carbon (g kg^{-1})	5.92
$KMnO_4$ – N (kg ha^{-1})	280.0
Olsen – P (kg ha^{-1})	14.50
NH_4OAc – K (kg ha^{-1})	384.5

Available P

The postharvest soils of kharif season rice crop registered the available P content of 14.5 kg ha^{-1}. The highest soil available P (16.30 kg ha^{-1}) was recorded in Rice – Black gram cropping sequence (T_3) that was at

par with Rice - Groundnut cropping sequence (T_7). A significant improvement in the status of mean available phosphorus was observed among different cropping sequences over the post-harvest soil of rice crop. It was reported that organic matter through release of various organic acids during decomposition, complexes those soil components which fix the P or complexes P itself thereby minimizing its fixation and immobilization by other soil components (Bahl and Singh, 1997 and Santhy, 1995) (Table 2 and 3).

Table 3. Influence of different cropping sequences on chemical properties (OC, Available N, P and K) of post-harvest soil

Treatment	OC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1 – Rice – Sunflower	5.46	277	14.76	378
T_2 – Rice – Sesame	5.43	281	13.50	272
T_3 – Rice – Blackgram	5.99	278	16.30	381
T_4 – Rice – Castor	6.22	284	15.50	383
T_5 – Rice – Maize	6.26	283	15.33	368
T_6 – Rice – Onion	6.05	275	13.38	384
T_7 – Rice – Groundnut	6.32	264	15.60	382
Mean	5.97	277	14.89	363
SEd	0.11	6.72	0.31	4.70
CD(p=0.05)	0.251	NS	0.68	10.2

Available K

The available K content of the postharvest soil of kharif season rice crop was 384 kg ha^{-1}. Among the seven cropping sequence studied in rabi season, the Rice – Onion cropping sequence (T_6)showed significantly higher available potassium (384.0 kg ha^{-1}) and it was on par with Rice – Groundnut (T_7), Rice – Castor (T_4), Rice - Black gram (T_3) and Rice-Sunflower (T_1) cropping sequences with the values of 382, 383, 381 and 378 kg ha^{-1} respectively. This may be due to the balanced use of fertilizers alone or conjoint use of inorganics with organics that results in a significant build-up of K. Similar results were also observed by (Verma *et al.*, 2012). The beneficial effects of FYM on the availability of K may be attributed to the reduction in K fixation and release of K due to the interaction of organic matter with clay (Table 2 and 3).

Table 4. Total nutrient uptake N, P and K of different cropping sequences

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1 – Rice – Sunflower	161.6	85.50	235.0
T_2 – Rice – Sesame	115.5	70.01	145.2
T_3 – Rice – Blackgram	155.6	43.73	121.1
T_4 – Rice – Castor	135.5	47.90	135.0
T_5 – Rice – Maize	296.3	63.63	235.1
T_6 – Rice – Onion	175.8	52.09	115.8
T_7 – Rice – Groundnut	211.8	63.50	177.2
Mean	178.8	60.80	166.8
SEd	3.78	1.29	3.01
CD(p=0.05)	8.23	2.81	6.56

Total N uptake

Among the cropping sequences, Rice – Maize cropping sequence (T_5), registered significantly highest total N uptake of 296.3 kg ha^{-1} and the lowest was found in Rice – Sesame cropping sequence (T_2) (115.5 kg ha^{-1}). This increase in total N uptake was statistically significant. This might be due to well-developed root system under the balanced application of nutrients through improved soil fertility. This is in agreement with the findings of (Meena *et al.*, 2017) who reported that the use of FYM with 100 per cent NPK led to a favourable soil environment besides proper nutrients, supply, which improved the crop growth and increased the wheat yield, resulting in higher N uptake (Table 4)

Total P uptake

The mean total P uptake ranged from a minimum of 43.73 kg ha^{-1} with Rice – Black gram cropping sequence (T_3) and the maximum of 85.50 kg ha^{-1} in Rice – Sunflower cropping sequence (T_1). This increase in total P uptake was statistically significant. Successive addition of fertilizer had resulted in higher content and uptake by grain and stalk of sunflower.

This could be due to successive addition of P through fertilizer which had resulted in proportionately higher availability in the soil for its subsequent uptake and utilization by plants. A similar finding was also observed by (Patidar, 2014) (Table 4).

Table 5. Crop yield and yield attributes under different rice based cropping sequences

Cropping sequence	Economic yield of rice (kg ha^{-1})	Economic yield of rabi crop (kg ha^{-1})	Stover yield (kg ha^{-1})		Biological yield of other crops (kg ha^{-1})		Price per kg of grains		Rice equivalent yield (kg ha^{-1})
			Rice	Other crops	Rice	Other crops	Rice	Other crops	
T_1 – Rice-Sunflower	5620.0	1500.0	7050.0	3330.0	12670	4830.00	15	32	3200.0
T_2 – Rice- Sesame	5620.0	866.00	7050.0	2797.0	12670	3663.00	15	60	3464.0
T_3–Rice- Blackgram	5620.0	550.00	7050.0	1200.0	12670	1750.00	15	40	2152.0
T_4 – Rice- Castor	5620.0	2029.0	7050.0	4032.0	12670	6061.00	15	41	5545.1
T_5 – Rice- Maize	5620.0	4224.0	7050.0	6766.0	12670	10990.0	15	15	4224.3
T_6 – Rice- Onion	5620.0	2333.0	7050.0	2677.0	12670	5010.00	15	30	4666.1
T_7–Rice- Groundnut	5620.0	2500.0	7050.0	8166.0	12670	10666.0	15	40	6666.6
Mean	5620.0	2000.3	7050.0	4179.5	12670	6138.0	15	36.8	4274.8
SEd	79.65	56.94	129.9	106.8	235.0	186.20	0.29	0.63	66.23
CD (P= 0.05)	NS	124.0	NS	232.9	NS	405.74	NS	1.38	144.3

Total K uptake

The significantly highest mean total K uptake was found with Rice - Maize cropping sequence (T_5) (235.1 kg ha^{-1}) that was on par with Rice – Sunflower cropping sequence (T_1) (235.0 kg ha^{-1}). The minimum total K uptake was registered with Rice – Onion cropping sequence (T_6) (115.8 kg ha^{-1}) and with Rice - Black gram cropping sequence (T_3) (121.1 kg ha^{-1}) that were on par. The effect of total K uptake was statistically significant. Application of FYM along with an optimal dose of fertilizers recorded the highest K uptake, which might be due to the favourable conditions of crop growth in these cropping sequence particularly improved soil fertility in turn enhanced plant K uptake. This was in line with the findings of (Meena *et al.*, 2017) (Table 4).

Table 6. Economic returns and benefit cost ratio of different cropping sequences

Cropping sequence	Gross return of rice (Rs.ha^{-1})	Gross return of other crops (Rs. ha^{-1})	Net return of rice (Rs.ha^{-1})	Net return of other crops (Rs.ha^{-1})	Cost of cultivation of rice (Rs.ha^{-1})	Cost of cultivation of other crops (Rs.ha^{-1})	B:C
T_1 – Rice-Sunflower	85275	43200	48575	18716	36700	24484	2.09
T_2 – Rice- Sesame	85275	39620	48575	17220	36700	22400	2.11
T_3–Rice- Blackgram	85275	35926	48575	13754	36700	22172	2.05
T_4 – Rice- Castor	85275	83189	48575	59913	36700	23276	2.80
T_5 – Rice- Maize	85275	66738	48575	16945	36700	49793	1.75
T_6 – Rice- Onion	85275	51437	48575	16291	36700	35146	1.90
T_7 – Rice- Groundnut	85275	38095	48575	64647	36700	26552	1.95
Mean	85287	51153	48509	29633	36735	29091	2.09
SEd	1519.5	1613.3	934.0	700.71	590.0	774.68	0.03
CD (P= 0.05)	NS	3515.5	NS	1526.8	NS	1688.0	0.08

Grain and stover yield

The mean value of kharif season rice economic yield was 5206 kg ha^{-1}. Among the seven cropping sequences studied, significantly highest economic yield was recorded in Rice – Maize (T_5) cropping sequence in maize crop (10990 kg ha^{-1}) followed by Rice – Groundnut (T_7) cropping sequence in groundnut crop (10660 kg ha^{-1}) which were on par. The higher economic yield might be due to higher biomass production and the higher nitrogen uptake because of balanced availability of nutrients through improved soil fertility. Similar findings in maize were also reported by Kleinkopf *et al.,*(1981) who reported that the economic yield of maize higher by producing higher biomass content and more uptake of nutrients.

The mean value of kharif season rice biological yield was 7050 kg ha^{-1}. Among the seven cropping sequences, the significantly highest biological yield was recorded in Rice – Groundnut cropping sequence (T_7) in groundnut crop (8166 kg ha^{-1}) and this was on par with Rice – Maize cropping sequence (T_5) in maize crop (6766 kg ha^{-1}) (Table 5).

Rice equivalent yield (REY)

The highest rice equivalent yield of 6666 kg ha^{-1} was registered in Rice – Groundnut cropping sequence (T_7) which was significantly superior over other cropping sequences. The lowest rice equivalent yield of 2152 kg ha^{-1} was recorded in Rice – Black gram cropping sequence (T_3). The Rice – Groundnut

(T_7) cropping sequence recorded highest REY which may be due to the highest cost per unit weight of groundnut and this sequence is also biologically efficient. Similar results were also reported in Gujarat Agricultural University (Gujarat Agricultural University, 2004) (Table 5).

Benefit : Cost ratio (B:C)

Comparing the seven cropping sequences studied, the highest BC ratio of 2.08 was recorded in Rice – Castor cropping sequence (T_4) which was statistically significant when compared to other cropping sequence. However, the highest net return of Rs. 1,13,222 ha^{-1} was found in Rice – Groundnut cropping sequence (T_7) followed by Rice – Castor cropping sequence (T_4) with Rs.1,08,488 ha^{-1}. The lowest cost of cultivation was recorded with Rice – Castor (T_4), Rice – Blackgram (T_3) and Rice – Sesame (T_2) cropping sequences with Rs. 59,979, Rs. 58,872 and Rs. 59,100 ha^{-1} respectively, which were on par. The lowest BC ratio of 1.90 was registered in Rice – Onion cropping sequence (T_6) and Rice – Groundnut cropping sequence (T_7) with 1.95 that were on par. This result is in line with (Virdia and Mehta, 2010) who also discussed that castor chosen being a rabi crop gives more profit in spite of less input consumption and hence higher BC ratio in paddy – castor cropping sequences when compared to paddy - groundnut (Fig 1).

Table 7. Water consumption of different cropping sequences

Treatment	No of irrigations		Quantity of water per irrigation (mm ha^{-1})		Total amount of water applied (mm ha^{-1})		Total amount of water consumed for different cropping systems (liters ha^{-1})
	Rice	Other crops	Rice	Other crops	Rice	Other crops	
T_1 – Rice - Sunflower	13	6	92*	75*	1196*	450*	1646 X 104
T_2 – Rice - Sesame	13	6	92*	83*	1196*	500*	1696 X 104
T_3 – Rice - Blackgram	13	4	92*	87*	1196*	350*	1546 X 104
T_4 – Rice - Castor	13	7	92*	45*	1196*	315*	1511 X 104
T_5 – Rice - Maize	13	5	92*	110*	1196*	550*	1746 X 104
T_6 – Rice - Onion	13	7	92*	65*	1196*	450*	1646 X 104
T_7 – Rice - Groundnut	13	6	92*	65*	1196*	390*	1586 X 104

Values in * represents (X 10^4) liters of water applied

Water consumption of different cropping sequences

The water consumption in Rice - Maize cropping sequence (T_5) was statistically superior over other cropping sequence. The lowest volume of water was consumed for Rice – Castor cropping sequences (T_4) with 1511 X 10^4 litre ha^{-1} which was also on par with the Rice – Black gram (T_3) and Rice – Groundnut (T_7) cropping sequences with the value of 1546 X 10^4 and 1586 X 10^4 litre ha^{-1} which may be due to the highest net return with the lowest cost of cultivation also consumed a comparatively minimum volume of water. The highest water consumed by Rice - Maize (T_5) cropping sequence is because maize is a C4 plant and requires more water for their production of photosynthatse. Wang *et al*., (2012) also observed in his study that photosynthesis efficiency of C_4 plants is 50 per cent higher than C_3 plants and hence consume more water than C_3 plants (Fig 2).

Conclusion

The present investigation on the influence of cropping sequences on soil nutrients status and crop yield, water consumption and economic returns were carried out. A positive impact of cropping sequences on fertility value of the soil was registered. The soil available N content was found to have an increasing trend over the initial soil value but the variation among the different cropping sequences was statistically insignificant because of differences in the depletion pattern of available N by the sequential crops. A significant improvement in the status of soil available phosphorus was observed on consequence of different cropping sequences over the initial soil. Among the seven cropping sequences studied, Rice – Groundnut (T_7) and Rice – Black gram (T_3) cropping sequences recorded the significantly highest soil available P content with an increase of 24.80 and 30.40 per cent over the initial value, respectively. The status of available potassium was also found favourably influenced by cropping sequences. Comparing the seven cropping sequences, the highest soil available K content was registered in Rice – Groundnut (T_7) cropping sequence with an increase of 0.73 per cent over the initial soil value. This was on par with Rice - Sunflower (T_1), Rice – Blackgram (T_3), Rice – Castor (T_4) and Rice – Onion (T_6) cropping sequences. A substantial increase in SOC content was observed due to the impact of cropping sequences. Significantly, higher magnitude of SOC was observed in Rice – Groundnut (T_7), Rice – Castor (T_4) and Rice – Maize (T_5) cropping sequences that were on par and showed an increase of 12.80, 11.10 and 11.00 per cent over the initial value, respectively

The highest economic returns was observed in the Rice – Castor cropping sequence (T_4) followed by the Rice – Groundnut (T_7) and Rice – Maize (T_5) cropping sequences with lowest water consumption, but owing to the consideration of sustained soil health over long run. Though castor being a long duration crop (150 days), it is also a hardy crop that requires minimum water consumption and withstand water stress conditions.

Thus, the results from the present investigation, considering the soil nutrients, quantity of water consumption, economic yield and BC ratio, the best alternative cropping sequence recommended for Parambikulam Aliyar command area is in the following order; Rice – Castor cropping sequence (T_4) followed by Rice – Groundnut cropping sequence (T_7) and Rice – Maize cropping sequences (T_5).

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