Soil and plant nutrient dynamics in castor-based cropping systems as influenced by conservation agricultural practices

ABSTRACT

A field experiment was conducted during *kharif* 2021, at Narkhoda farm, ICAR-Indian Institute of Oilseeds Research, to study the effect of conservation agricultural practices on soil and plant nutrient dynamics. The experiment was laid out in split-plot design with 3 replications on red sandy loam soil (*Alfisols*) under rainfed conditions. The treatments comprised of three tillage treatments in main plots *viz*., conventional tillage, reduced tillage, zero tillage and four cropping systems with residue incorporation in subplots *viz*., sole castor, castor + redgram (1:1), castor + greengram (1:3) and castor + groundnut (1:3).The results indicated that at harvest, highest soil organic carbon (SOC) content was found in reduced tillage (0.64%) followed by zero tillage (0.63%) and the lowest in conventional tillage (0.56%). Amonginter cropping systems, SOC was recorded highest (0.67%) in castor + redgram (1:1) and lowest (0.55%) in sole castor treatment. The status of post-harvest soil available N, P, K (kg/ha) was recorded highest in reduced tillage (208.6, 54.03, 515.9 kg N, P, K /ha respectively) and lowest in conventional tillage (196.7, 38.57, 486.8 kg N, P, K /ha) while, zero tillage (203.6, 47.15, 506.7 kg N, P, K /ha) was at par with the reduced tillage. Among the cropping systems, castor + redgram (208.1, 60.12, 517.9 kg N, P, K /ha) recorded highest available N, P, K while lowest in sole castor (201.6, 38.60, 494.0 kg N, P, K /ha) treatment. Total N, P, K uptake (kg/ha) by castor crop at harvest was highest in conventional tillage (56.13, 19.99, 31.97 kg N, P, K /ha respectively) followed by reduced (49.24, 16.81, 26.28 kg N, P, K /ha) and the lowest (38.36, 13.15, 21.99 kg N, P, K /ha) was recorded in zero tillage. Amongintercropping cropping systems N, P, K uptake by castor crop was recorded highest in sole castor (60.22, 18.66, 32.35 kg N, P, K /ha) treatment while lowest was recorded in castor + redgram (1:1) (26.65, 10.28, 15.93 kg N, P, K /ha). In general, the interaction effect between tillage and intercropping system were found non-significant.

Key words: Conservation agriculture, organic carbon, available N, P and K, nutrient uptake

1.INTRODUCTION

Castor is one of the oldest cultivated crops grown in arid, semi-arid regions and it contributes to 0.15% of the vegetable oil produced in the world. The oil produced from this crop is of importance to the global specialty chemical industry because it is the only commercial source of a hydroxylate fatty acid. In 2021-22, world major producing countries are India (18.42 lakh tonnes), Mozambique (0.85 lakh tonnes), China (0.27 lakh tonnes), Brazil (0.14 lakh tonnes) and Myanmar (0.12 lakh

tonnes). (FAO, 2022) Area under castor in India reported in 2021-22 was 6.96 lakh ha. Among states, Gujarat is leading with 5.38 lakh ha followed by Rajasthan (1.200 lakh ha), Andhra Pradesh (0.177 lakh ha) and Telangana (0.022 lakh ha) (IASRI, 2022).

Castor is popularly grown in Southern Telangana zone in Telangana state. The region falls under semi-arid tropics which is characterized by hot weather, low and erratic behaviour of rainfall which results in early or late season drought. In order to mitigate adverse effects of drought moisture-conservation practices are essential for successful cultivation of crops under aberrant weather conditions. The soils under rainfed regions are characterised by low inherent soil fertility and water holding capacity due to poor organic carbon content resulting in poor crop productivity. Restoration of soil organic carbon to sustain soil fertility in these regions is very critical. Further, continuous cultivation of crops in these regions depletes the organic carbon content, nutrients and moisture from the soil which affect the soil health. Hence, production technologies that maintain organic carbon at desired levels, conserve soil moisture content, reduce soil compaction, increase soil fertility will be greatly helpful to improve the soil health and sustain yields and monetary returns under rainfed conditions.

Conservation agriculture (CA), based on minimum mechanical soil disturbance, soil cover with crop residues or by growing cover crops, and diversified cropping systems, is well known to address the issues related to moisture stress and soil fertility constraints. Residue retention combined with minimum mechanical soil disturbance, intercropping with the legume crops builds up soil organic matter (SOM), although the increasing rate is climate, soil, and management dependent. Improved SOM and aggregation at the soil surface also leads to increased nutrient use efficiency. CA sustains soil fertility as a result of reduced runoff and leaching losses of nutrients, release of nutrients from residues and increased activity of soil microorganisms *etc*., (Jat*et al*., 2020).

2.MATERIALS AND METHODS

A field experiment was conducted to study the effect of conservation agricultural practices on soil and plant nutrient dynamics in castor-based cropping system under rainfed conditions during the year 2021-2022 at ICAR-IIOR Narkhoda farm, Shamshabad, Hyderabad. The farm is situated at an altitude of 581m and geographical bearing of 17^0 15' 39.8'' N latitude and 78^0 18' 55.5'' E longitude. The weekly mean maximum and minimum temperature during crop growth period recorded was 30.8^o C and 18.1^o C respectively. The total rainfall of 989.4mm in 76 rainy days was received during the crop growth period.

The design of the experiment was split plot with 3 types of tillage as main plot treatments and 4 cropping systems as subplot treatments. M_1- CT-Conventional tillage (One disc plough+ two cultivators + rota tiller), M_2- RT-Reduced tillage (One cultivator + one rota tiller-no disc plough), M_3- ZT-Zero tillage while the sub-plot treatments consist of S_1- Sole castor, S_2- Castor+ redgram (for grain and cut in situ spread) (1:1), S_3- Castor+ greengram (for grain and uprooted and in situ spread) (1:3) and S_4- Castor + groundnut (1:3).

Zero-tillage is an extreme form of minimum tillage, in which primary tillage is completely avoided and secondary tillage is restricted to seed bed preparation in row zone only. In zero tillage plots Glyphosate (30 % EC) @ 1.0 kg *a.i* ha^{-1} was sprayed 1 month prior to the sowing to control and manage perennial weeds. The experiment was conducted on sandy loam soil (*Alfisols*) characterized by shallow to medium depth having 0.49% soil organic carbon, 185.3 kg/ha available nitrogen, 57.25 kg/ha available phosphorous, 537.8 kg/ha available potassium. Soil organic carbon was estimated by using the Walkley and black method (Jackson, 1973) Available nitrogen in the soil was estimated by alkaline permanganate method (Subbaiah and Asija, 1956). Available phosphorus in the soil sample was extracted with Olsen's method (Olsen et al., 1954). Available potassium was determined by using flame photometer method (Jackson, 1973). Nutrient uptake (N, P, K) by crop was estimated by following the standard measures (Piper, 1966).

3.RESULTS AND DISCUSSION

3.1Soil organic carbon (SOC): The data pertaining to soil organic carbonis been presented in Table. 1.

There was significant influence of tillage treatments and differentintercropping systems on build-up of soil organic carbon at harvest. SOC was found to be highest in reduced tillage (0.64%) followed by the zero tillage (0.63%) and thelowest was observed in conventional tillage (0.56%). Among the different inter cropping systemshighest soil carbon content was found in castor + redgram (0.67%) but was on par with castor + greengram (0.65%) followed by castor + groundnut (0.60%) and the lowest was observed in sole castor (0.57%) treatment. The increased organiccarbon in reduced and zero tillage might be due tothe addition of crop residues and reducedrateofits decompositionin the above tillage practices.These findings are in corroboration with results ofLal, 2010. The lowest SOC was noticed in conventional tillage (value) might be due to regular disturbance and exposure of soil in this treatment. Similarly, Follet (2001) attributed thatrelativelyhighsoildisruptionhad intensifiedoxidation of soil organic matter. High SOC was found incastor+ redgram treatment and this might be due to higherbiomass addition through redgram as compared to castor + greengram, sole castor residues. This was also reported by Jat*et al*. (2020).

3.2Soil available N, P, K: Tillage and intercropping systems exerted significant influence on postharvest available soil N, P, K (Table.1). However, the interaction effect was found to be non-signififcant. Highest available N, P, K was recorded in reduced tillage (208.6, 54.03, 515.9 kg N, P, K /ha respectively) but it was at par with zero tillage (203.6, 47.15, 506.7 kg N, P, K /ha respectively) and the lowest was recorded in conventional tillage (196.7, 38.57, 486.8 kg N, P, K /ha respectively). Among the intercropping systems castor + redgram (1:1) recorded the highest available postharvest soil N, P, K (208.1, 60.12, 517.9 kg N, P, K /ha) but was on par with castor + greengram (1:3) (205.78, 51.90, 508.98 kg N, P, K /ha). In castor + groundnut treatment available nitrogen and potassium (203.5, 504.3 kg N, K /ha) was found at par with the castor + greengram treatment while available phosphorous (46.99 kg/ha) in castor + groundnut followed the castor + greengram treatment. Available N, P, K in sole castor plots (201.6, 38.60, 494.0 kg N, P, K /ha respectively) was found at par with the castor + groundnut system. CA basedpractices like inclusion of legumes in cropping

systems, application of residues as soil mulch led to greater availability of both native and applied nutrients in the soil which can be attributed toreduced runoff loss of nutrients and release of nutrients from decomposing crop residues while increase in the organic carbon content(FAO, 2001).The reason for improved organic carbon in reduced and zero tillage was due to addition of crop residues and reducedrateofdecompositionofcropresidues, plantrootsandaccumulation of organic matter in the soil by the fauna and flora (Lal, 2010). The lowest SOC in conventional tillage is attributed to relativelymoresoildisruption and intensifyingoxidation of soil organic matter (Follet, 2001). Higher SOC was found in redgram treatment was due to higherbiomass addition through redgram, residues as compared to greengram, castor residues which was reported by Jat*et al*. (2020).

Table1. Effect of tillage and castor based intercropping system on available soil organic carbon (%) andavailable N, P, K (kg/ha) at harvest

Treatment	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Main plots (M)				
M_1-Conventional tillage	0.56	196.7	38.57	486.8
M_2-Reduced tillage	0.64	208.6	54.03	515.9
M_3-Zero tillage	0.63	203.6	47.15	506.7
SEm±	0.007	1.98	2.55	6.34
CD (P=0.05)	0.019	5.89	7.58	18.85
Sub plots (S)				
S_1-Sole Castor	0.55	201.6	38.60	494.04
S_2-Castor +Redgram (1:1)	0.67	208.1	60.12	517.9
S_3-Castor +Greengram (1:3)	0.65	205.7	51.90	508.9
S_4-Castor +Groundnut (1:3)	0.60	203.5	46.99	504.3
SEm±	0.016	1.38	2.95	4.17
CD (P=0.05)	0.046	4.10	8.77	12.4
Interaction				
MxS				
SEm±	0.027	4.70	5.11	21.12
CD (P=0.05)	NS	NS	NS	NS
S x M				
SEm±	0.028	4.90	5.27	32.97
CD (P=0.05)	NS	NS	NS	NS

3.3N, P, K uptake by castor stalk at harvest: The data pertaining to uptake of N, P, K by castor stalks at harvest were presented in Table. 2.

N, P, K uptake by castor stalk was found significantly higher in conventional tillage (18.12, 9.98, 14.94 kg N, P, K /ha respectively) followed by reduced tillage (13.74, 7.88, 11.93 kg N, P, K /ha respectively). In case of zero tillage N, P, K uptake (13.73, 7.26, 11.95 kg N, P, K /ha respectively) was on par with the reduced tillage. Similar results were reported by Gaun*et al*. (2014) who observed highest uptake of nutrients in CT over RT and ZT that could be attributed to lower bulk density, penetration resistancethat improved root growth and higher nutrient uptake.

Among the inter-cropping systems there was a significant difference in the N, P, K uptake. From the (Table. 4) it is evident that highest N uptake was found in sole castor (18.32 kg/ha)but it was at par with castor + greengram (17.15 kg/ha), followed by castor + groundnut (16.45 kg/ha) and lowest was observed in castor + redgram (8.87 kg/ha) treatment. P uptake was highest in castor + greengram (9.68 kg/ha) while castor+ groundnut (9.40 kg/ha), sole castor (9.18 kg/ha) was found at par with it. Castor + red gram (5.24 kg/ha) recorded the lowest uptake. Potassium uptake was highest in sole castor treatment (14.92 kg/ha) while castor + greengram (14.81 kg/ha), castor +groundnut (13.99 kg/ha) was at par with it and the lowest uptake was recorded in castor +redgram (8.03 kg/ha) treatment. The interaction effect of tillage and intercropping system on nutrient uptake by castor stalk was found to be non-significant.Nutrient uptake was found highest in sole castor over the intercropping systems that could be attributed to aggressive competition of intercrops for nutrients that reduced the biomass of castor plants in the intercropping treatments over the sole crop. Similar results were documented by Basith and Mohammad (2010) in castor.

Table2. Effect of tillage and castor based intercropping system on N, P, K uptake by castor (stalk) at harvest stage

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Main plots (M)			
M_1-Conventional tillage	18.12	9.98	14.94
M_2-Reduced tillage	13.74	7.88	11.93
M_3-Zero tillage	13.73	7.26	11.95
SEm±	0.64	0.36	0.50
CD (P=0.05)	1.91	1.08	1.51
Sub plots (S)			
S_1-Sole Castor	18.32	9.18	14.92
S_2-Castor + Redgram (1:1)	8.87	5.24	8.03
S_3-Castor + Greengram (1:3)	17.15	9.68	14.81
S_4-Castor + Groundnut (1:3)	16.45	9.40	13.99
SEm±	0.53	0.31	0.40
CD (P=0.05)	1.59	0.94	1.20
Interaction			
MxS			
SEm±	0..93	0.55	0.64
CD (P=0.05)	NS	NS	NS
S x M			
SEm±	1.19	0.69	0.82
CD (P=0.05)	NS	NS	NS

3.4N, P, K uptake by castor seed at harvest: Data pertaining to N, P, K uptake by castor seed at harvest were presented in Table. 3.

Among the three tillage treatments there was similar trend observed in nitrogen, phosphorous uptake and varied in potassium uptake. Conventional tillage (38.01, 10.01 kg N, P /ha respectively) recorded the highest uptake of N, Pand it was found on par with reduced tillage (35.50, 8.93 kg N, P

/ha respectively) while lowest N, P uptake was recorded in zero tillage (24.63, 5.90 kg N, P /ha respectively). K uptake was found highest in conventional tillage (17.03 kg/ha) followed by reduced tillage (14.35 kg/ha) and lowest K uptake was recorded in zero tillage (10.04 kg/ha). Similar results were reported by Gaun*et al*. (2014) who observed highest uptake of nutrients in CT over RT and ZT that could be attributed to lower bulk density, penetration resistance that improved root growth and higher nutrient uptake.

There was significant influence of inter-cropping systems on N, P, K uptake by castor seed. Highest N, K uptake was found in sole castor treatment (41.9, 17.43 kg N, K /ha respectively) and it was on par with castor + groundnut (38.59, 15.90 kg N, K /ha respectively). It was followed by castor + greengram treatment (32.60, 14.01 kg N, K /ha respectively) while castor + redgram (17.77, 7.90 kg N, K /ha respectively) recorded the lowest uptake. Puptake was recorded highest in castor + groundnut (9.78 kg/ha) treatment and it was on par with sole castor (9.45 kg/ha), castor + greengram (8.81 kg/ha) while lowest was recorded in castor + redgram (5.04 kg/ha) treatment. The interaction effect of tillage and intercropping system on nutrient uptake by castor seed was found to be non-significant.

Nutrient uptake was found highest in sole castor over the intercropping systems that could be attributed to aggressive competition of intercrops for nutrients that reduced the biomass of castor plants in the intercropping treatments over the sole crop. Similar results were documented by Basith and Mohammad (2010) in castor.

3.5Total N, P, K uptake by castor crop: Data pertaining to total N, P, K uptake at harvest by castor crop were presented in Table. 4. There was significant influence of tillage and intercropping systems on total uptake of N, P, K uptake by the crop at harvest.

Among the tillage treatments similar trend was observed on N, P, K uptake by the crop. The highest N, P, K uptake was found in conventional tillage (56.13, 19.99, 31.97 kg N, P, K /ha respectively) it was followed by reduced tillage (49.24, 16.81, 26.28 kg N, P, K /ha respectively) and lowest uptake was observed in zero tillage (38.36, 13.15 kg/ha, 21.99 kg N, P, K /ha respectively). Similar results were reported by Gaun*et al*. (2014) who observed highest uptake of nutrients in CT over RT and ZT that could be attributed to lower bulk density, penetration resistance that improved root growth and higher nutrient uptake.

Among the different intercropping systems N, K uptake followed the similar trend. Highest N, K uptake was found in sole castor (60.22, 32.35 kg N, K /ha respectively) treatment and was on par with castor + groundnut (55.03, 29.89 kg N, K /ha respectively) in turn castor + groundnut was on par with the castor + greengram (49.74, 28.82 kg N, K /ha respectively) treatment and lowest N, K uptake was found in castor + redgram (26.65, 15.93 kg N, K /ha respectively) treatment. The total Puptake was found significantly highest in castor + groundnut (19.18 kg/ha) while it was on par with sole castor (18.66 kg/ha), castor + greengram (18.49 kg/ha) and lowest was recorded in castor + redgram (10.28 kg/ha). The interaction effect of tillage and intercropping system on nutrient uptake by castor crop was found to be non-significant.

Nutrient uptake was found highest in sole castor over the intercropping systems that could be attributed to aggressive competition of intercrops for nutrients that reduced the biomass of castor plants in the intercropping treatments over the sole crop. Similar results were documented by Basith and Mohammad (2010) in castor.

Table3. Effect of tillage and castor based intercropping system onuptake of N, P, K by castor (seed)

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Main plots (M)			
M_1-Conventional tillage	38.01	10.01	17.03
M_2-Reduced tillage	35.50	8.93	14.35
M_3-Zero tillage	24.63	5.90	10.04
SEm±	2.07	0.61	1.17
CD (P=0.05)	6.15	1.82	3.31
Sub plots (S)			
S_1-Sole Castor	41.90	9.45	17.43
S_2-Castor + Redgram (1:1)	17.77	5.04	7.90
S_3-Castor + Greengram (1:3)	32.60	8.81	14.01
S_4-Castor + Groundnut (1:3)	38.59	9.78	15.90
SEm±	1.79	0.45	0.77
CD (P=0.05)	5.31	1.35	2.31
Interaction			
MxS			
SEm±	3.10	0.79	1.35
CD (P=0.05)	NS	NS	NS
S x M			
SEm±	3.91	1.06	1.86
CD (P=0.05)	NS	NS	NS

Table4. Effect of tillage and castor based intercropping system on total uptake of N, P, K by castor at harvest

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Main plots (M)			
M_1-Conventional Tillage	56.13	19.99	31.97
M_2-Reduced Tillage	49.24	16.81	26.28
M_3-Zero Tillage	38.36	13.15	21.99
SEm±	2.07	0.54	1.094
CD (P=0.05)	6.15	1.63	3.25
Sub plots (S)			
S_1-Sole Castor	60.22	18.66	32.35
S_2-Castor + Redgram (1:1)	26.65	10.28	15.93
S_3-Castor + Greengram (1:3)	49.74	18.49	28.82
S_4-Castor + Groundnut (1:3)	55.03	19.18	29.89
SEm±	1.9	0.59	1.03
CD (P=0.05)	5.9	1.75	3.07
Interaction			
MxS			
SEm±	3.45	1.02	1.79
CD (P=0.05)	NS	NS	NS
S x M			
SEm±	4.20	1.20	2.19
CD (P=0.05)	NS	NS	NS

4. CONCLUSIONSAND RECOMMENDATIONS

Results of the study demonstrated that addition of residues in soil and inclusion of legumes in cropping systems enhanced the soil fertility by improving soil organic carbon. Nutrient uptake was recorded highest in conventional tillage over the reduced and zero tillage and among the cropping systems sole cropping recorded the highest uptake against the intercropping system.Adoption of conservation agriculture practices had improved the soil fertility while the nutrient uptake and yields were reduced due to unfavourable soil conditions and competition from the intercrops.However, nutrient uptake and crop yield gap between the CT and ZT had narrowing down effect over the years, it time to realize the benefits of ZT as the positive effects of CA on yields, nutrient uptake can be realized in long term period.

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