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***Research article***

# EFFECTS OF CONSERVATION AGRICULTURE PRODUCTION SYSTEM (CAPS) ON SOIL ORGANIC CARBON, BASE EXCHANGE CHARACTERISTICS AND NUTRIENT DISTRIBUTION IN A TROPICAL RAINFED AGRO-ECOSYSTEM.

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**ABSTRACT:** Conservation agriculture production system (CAPS) with the components of minimum tillage, legume based intercrops and follow up cover crop has been established in a *Fluventic Haplustepts* at Regional Research and Technology Transfer Station, OUAT, in Kendujhar district ,Odisha during 2011 in triplicated split plot design and the impacts of Conservation Agriculture Production System (CAPS) on soil organic matter, base exchange characteristics and available nutrients were assessed at the end of the 2nd cropping cycle. The treatment combinations are conventional tillage (CT) and minimum tillage (MT) with sole maize (M) and inter crop maize+ cowpea (M+C) in main-plots during wet season and horsegram (H), mustard (T) and no cover crop (NCC) in sub-plots during dry season. The accumulation and preservation of organic matter in MT increased the SOC (+19.9 %), CEC (+11.2 %), $Ca^{++}$ (+19.9 %), $Mg^{++}$(+18.3%), $K^{+}$(+14.9%), base saturation (+6.7%) over the soils under CT system. Higher build up of and physical protection of SOM due to less soil disturbances in MT resulted in higher available N (+13.4%), P (+3.9%) and K (+10.1%). The pronounced effect of cover crops due to litter inputs in the cropping system was reflected on enhanced SOC (+6.8%), $Ca^{++}$ (+6.5%), $Mg^{++}$ (+5.8%), $K^{+}$ (+4.7%), available N (+5.1%) and P (+6.3%), over the soils with NCC. Considerable build up of SOC due to residue incorporation and its protection under the CAPS of MT with M+C intercrop and a follow up cover crop contributed significantly in improving the status of CEC (r =0.57**), base saturation (r = 0.54**),available N(r =0.77**), P (r =0.47*) and K(r =0.63**).
**Key words:** Available nutrients, Base Exchange, Cover crops, Soil organic carbon, Tillage.

## INTRODUCTION

SOC, as the primary source of plant nutrients, plays a major role in nutrient cycling and is positively correlated with soil nutrients, water holding capacity, infiltration capacity, aggregate formation and soil health [9]. Decline in SOC results in both the on-site and off-site impacts of land degradation because of its multi-functions. In the North Central Table land zone of Odisha in the eastern parts of India, poor soil fertility is attributed to continuous maize monoculture and tillage induced soil erosion. Medium textured, shallow and highly erodible young soils derived from the colluvial-alluvial deposits in this tract are low in organic matter. Improvements in SOM can result in several benefits in the soils, including improved soil nutrient storage capacity, nutrient availability, biological activity, soil structure and resistance to erosion [3]. The dynamics of SOM are influenced by agricultural management practices such as tillage, mulching, removal of crop residues and cropping systems. Soil biological and chemical properties most impacted by tillage methods are SOC content, pH, CEC, exchangeable cations and soil fertility [8]. Conventional tillage increases soil degradation, reducing soil productivity and SOC whereas reduced or no till practices can increase SOC in the surface soil layer [7]. Removal of crop residues from the fields is known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage [22].

Conservation agriculture (CA) is characterized by three principles which are linked to each other in a mutually reinforcing manner namely: (a) continuous no or minimal mechanical soil disturbance (b) permanent organic matter soil cover, especially by crop residues and cover crops and (c) diversified crop rotations or plant associations [11]. Conservation agriculture production system (CAPS) involving minimum tillage, legume based intercrop and cover crops have been introduced in this hilly, rainfed agro-ecosystem in 2011 with an objective to restore the soil and environmental qualities. The objectives of the present study were to assess the effects of maize based CAPS on SOC, available nutrients and base exchange characteristics of soils after the 2$^{nd}$ cropping cycle.

## MATERIALS AND METHODS

A long term field experiment with conservation agriculture production system was established in the year 2011 at Regional Research and Technology Transfer Station of Orissa University of Agriculture and Technology, Kendujhar (20$^0$50´E, 85$^0$34´N, and 499 m above mean sea level), Odisha, India. It has a hot, moist sub humid climate with mean annual temperature of 25.4$^0$C and an average annual rain fall of 1527 mm received mostly during the monsoon months of July to September. The soil developed from colluvial alluvial deposits in a piedmont plain is classified as *Fluventic Haplustepts* (Soil Taxonomy) with sandy clay loam surface texture. The treatments are conventional tillage (CT) and minimum tillage (MT) with sole maize (M) and maize + cowpea intercrop (M+C) in main plots during dry season and fallow (NCC), horse gram (H) and toria mustard (T) in subplots during dry season, resulting a total of 12 treatment combinations. The experiment was designed in split plots with three replications. The conventional tillage (CT) involves three mould board ploughing without residue incorporation to a depth of 20-25 cm and in minimum tillage (MT), one shallow disking is done up to a depth of 10 cm with addition of chopped main crop (maize, cowpea) and cover crops (horse gram, toria mustard) biomass as surface residues.

The initial composite soil samples prior to the establishment of the experiment (2011) and soil samples from individual experimental plots after the end of 2$^{nd}$ cropping cycle, drawn from a depth of 0-10 cm, were gently ground and passed through a 2 mm sieve. The soils were then analyzed for pH, organic carbon [21], available N [19], P [14], K [5], CEC by ammonium saturation [4], exchangeable $Ca^{++}$, $Mg^{++}$ and $K^+$ [15].

## RESULTS AND DISCUSSION

### Soil Organic Carbon and pH

Lower physical impact due to tillage reduction in association with residue buildup increased the soil organic carbon (SOC) significantly (+19.9%) in MT over CT systems (6.46 g kg$^{-1}$) within a short period of two years. Protecting the soil under cover crops during dry season also enhanced the SOC contents (+6.6%) over NCC (6.81 g kg$^{-1}$).The increase of SOC under the MT systems with cover crops was probably associated with the higher input of crop residues and the lower rate of soil organic matter decomposition compared with those under the CT systems [16]. In contrast, conventional tillage (CT) disrupts macro-aggregates due to intense physical activity and exposes the formerly incorporated SOC to microbial decomposition [18]. The pH of the soils under different tillage and cropping systems did not show any significant variation even after completion of two cropping cycles.

### Available N, P and K

Accumulation of crop residues and preservation of organic matter have significant effects on available pools of soil N, P and K in the surface soils (Table 1) under MT systems. Practice of MT two years in succession, increased the available N of soils by13.4% over the CT (269.6 kg ha$^{-1}$). The increase in available P and K under MT were in the tune of 3.9% and 10.1%, respectively as compared to CT. The buildup of SOM in the soils under cover cropping enhanced the contents of available N (+5.1%) and P (+6.3%) over the soils under no cover crops (NCC).Due to the residue mulch, MT systems generally provide a favourable temperature and moisture conditions for a more regular SOM decomposition throughout the cropping cycle resulting in higher N availability [1].
Against the background of improved SOC and nitrogen, P solubilization was greater in the top soils under MT [23] and the increased P availability under MT might be due to decreasing adsorption of P to the mineral surfaces [13]. Kuotsu *et al*. [6] reported that the available P under residue mulching may be due to reduced fixation of water soluble P and increase in mineralization of organic P. Contribution of SOM to the available pool of soil K in the top soils under MT has been reported by Thomas *et al*.,[20], Qin *et al*., [16].

**Table 1. Effect of tillage and cropping systems on pH, soil organic carbon, available N, P and K contents**

| Treatments | pH (1:2.5) | SOC (g kg$^{-1}$) | Available N (kg ha$^{-1}$) | Available P (kg ha$^{-1}$) | Available K (kg ha$^{-1}$) |
|---|---|---|---|---|---|
| Initial | 7.51 | 6.62 | 266.6 | 15.73 | 340.9 |
| Main plot | | | | | |
| CT-M | 7.34 | 6.12 | 259.3 | 15.49 | 320.9 |
| CT-M+C | 7.32 | 6.80 | 279.8 | 17.32 | 339.0 |
| MT-M | 7.28 | 7.58 | 300.1 | 16.20 | 356.0 |
| MT-M+C | 7.27 | 7.93 | 309.6 | 17.91 | 371.2 |
| LSD (0.05) | NS | 0.60 | 23.2 | 1.55 | 32.8 |
| Sub plot | | | | | |
| NCC | 7.33 | 6.81 | 277.7 | 16.05 | 341.1 |
| H | 7.28 | 7.54 | 298.6 | 17.43 | 353.5 |
| T | 7.29 | 6.98 | 285.3 | 16.71 | 345.7 |
| LSD(0.05) | 0.04 | 0.33 | 10.8 | 1.04 | NS |
| Interaction | NS | NS | NS | NS | NS |

CT: Conventional tillage, MT: Minimum tillage, M: Maize, C: Cowpea, NCC: No cover crop, H: Horsegram, T: Mustard, SOC: Soil organic carbon

**Table 2. Effect of tillage and cropping systems on CEC, exchangeable bases and base saturation**

| Treatments | CEC | Exchangeable bases | | | Base Saturation |
|---|---|---|---|---|---|
| | | $Ca^{++}$ | $Mg^{++}$ | $K^{+}$ | |
| | c mol (p$^{+}$) kg$^{-1}$ | | | | (%) |
| Initial | 25.32 | 13.65 | 5.51 | 1.68 | 78.3 |
| Main plot | | | | | |
| CT-M | 25.34 | 12.16 | 5.02 | 1.56 | 75.5 |
| CT-M+C | 27.14 | 13.74 | 5.46 | 1.66 | 78.29 |
| MT-M | 28.44 | 15.06 | 6.05 | 1.84 | 81.91 |
| MT-M+C | 29.93 | 16.00 | 6.35 | 1.87 | 82.24 |
| LSD (0.05) | 2.09 | 1.03 | 0.46 | 0.06 | 4.49 |
| Sub plot | | | | | |
| NCC | 27.28 | 13.65 | 5.51 | 1.68 | 77.67 |
| H | 28.28 | 14.87 | 6.01 | 1.78 | 81.33 |
| T | 25.58 | 14.21 | 5.66 | 1.74 | 79.47 |
| LSD(0.05) | NS | 0.88 | 0.33 | 0.08 | NS |
| Interaction | NS | NS | NS | NS | NS |

CT: Conventional tillage, MT: Minimum tillage, M: Maize, C: Cowpea, NCC: No cover crop, H: Horsegram, T: Mustard, CEC: Cation exchange capacity

**Table 3. Correlation among measured soil attributes across all treatments**

| Soil attributes | pH | SOC g kg$^{-1}$ | Av. N kg ha$^{-1}$ | Av. P kg ha$^{-1}$ | Av. K kg ha$^{-1}$ | CEC c mol (p+) kg$^{-1}$ | BS % |
|---|---|---|---|---|---|---|---|
| **pH** | 1 | | | | | | |
| **SOCg kg$^{-1}$** | -0.485** | 1 | | | | | |
| **Av. Nkg ha$^{-1}$** | -0.509** | 0.773** | 1 | | | | |
| **Av. Pkg ha$^{-1}$** | -0.297 | 0.467** | 0.489** | 1 | | | |
| **Av. Kkg ha$^{-1}$** | -0.501** | 0.633** | 0.631** | 0.426** | 1 | | |
| **CECc mol (p+) kg$^{-1}$** | -0.093 | 0.571** | 0.544** | 0.488** | 0.524** | 1 | |
| **BS%** | -0.660** | 0.543** | 0.553** | 0.220 | 0.388** | -0.091 | 1 |

* Correlation is significant at P<0.05

### Base Exchange Characteristics

Adoption of MT enhanced the CEC of soils even within a short span of two years and the increase was in the tune of 11.2% over CT system {26.2 c mol ($p^+$) $kg^{-1}$}. The soils under cover crops, however, did not show any significant changes in CEC. The effect of SOM on the point of zero charge ($pH_O$) of the soil variable charge component is considered to be the most important aspect in increasing $CEC_V$.The greater the difference between the soil pH and $pH_O$, the greater is the net surface charges due to variable charge component and SOM has a low $pH_O$ due to presence of carboxyl groups [12]. The significant contribution of the elevated stock of SOM to soil CEC has been reported by Rashidi *et al*. [17]. Ben Moussa-Machraoui *et al*. [2] found greater organic matter accompanied by a corresponding increase in CEC under no tillage compared to conventional tillage. The treatments under MT showed significant increase in the exchangeable $Ca^{++}$ (+19.9%), $Mg^{++}$ (+18.3%) and $K^+$ (+14.9%) over its tillage counterpart (CT). The elevated and preserved SOM due to cover crops also contributed significantly to exchangeable $Ca^{++}$ (+6.5%), $Mg^{++}$ (+5.8%) and $K^+$ (+4.7%) as compared to NCC.A higher concentration of exchangeable bases in the surface layers of soils with MT appeared to be due to the return of crop residues on the soil surface. There are several pieces of research documenting this fact [10, 20]. Soils under reduced tillage (MT) have higher base saturation (+6.7%) over CT (76.9%).

The correlation matrix developed for seven soil parameters (Table 3) showed several correlations among the variables with significant relationships ($P<0.05$) being identified for seventeen of the twenty one soil parameter pairs. The significant correlations between the soil parameters indicate their strong interrelationship. The strong positive correlation of SOC with available N (r = 0.77**), P (r = 0.47**), K (r = 0.63**), CEC (r = 0.57**), base saturation (r = 0.54**) justifies the contribution of SOC in improving these soil parameters.

## CONCLUSION

The buildup of SOM due to accumulation of litter inputs on the soil surface and their protection due to reduced soil inversion under the conservation agriculture production system (CAPS) of minimum tillage with maize + cowpea intercrop and a follow up horse gram cover crop helps to improve the available nutrient pools, CEC and base exchange characteristics within short span of two years. The intense physical impacts in conventional tillage, on the other hand, resulted in loss of SOC stock over a period of time. The CAPS comprising MT with maize cowpea intercrop in wet season and horse gram as cover crop in dry season appeared to be the most suitable choice in restoring the soil health of the erosion prone sloppy terrains under the North Central Plateau zone of Odisha.

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