Effect of protracted fertilization and manuring on changeable pools of soil organic matter in four different soil types with wheat-based cropping systems of India

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Abstract
Long term effect of manuring and fertilization on the SOM fractions e.g. hot water extractable C (HWEOM-C) and hot water extractable N (HWEOM-N) pool of SOC were studied in four major soil groups of India. The soil samples were collected in the year 2015 to a depth of 0–15 cm and 15-30 cm from the fields of All India Coordinated Project (AICRP) on Integrated Farming System continuing since 1983. The treatments comprised of control, 100%NPK, 50%NPK+50%FYM, 50%NPK+50%N-CR and 50%NPK+50%GM and green manuring crops like Sesbania (Sesbania aculeate L. in Ludhiana), Green gram (Vigna radiata L. in Pantnagar), Sunhemp (Crotalaria juncea L. in Jabalpur), Karanj (Pongamia pinnata L. in Ranchi). The results indicated that Hot water extractable carbon (HWEOM-C I, II) was highest in 50%NPK+50%FYM in both the soil depths for Pantnagar (Mollisol), Jabalpur (Vertisol) and Ranchi (Allisol) but in Ludhiana (Inceptisol), HWEOM-C I was highest in 50%NPK+50%FYM and HWEOM-C II in 50%NPK+50%GM in both the soil depths. Hot water extractable nitrogen (HWEOM-N) was highest in 50%NPK+50%GM for all soil orders in both the soil depths.

Keywords: Soil organic matter, soil organic carbon, labile pools, water extractable nitrogen, soil quality

1. Introduction
Soil organic matter (SOM) has been identified as a key factor in maintaining soil quality and crop production (Doran and Parkin, 1994) [9]. It contributes directly to plant and microbial growth through its influences on soil chemical, physical and biological properties (Reeves, 1997) [26]. It is likely that constant organic matter supply through manure or crop residue application favours high level of microbial activities and production of binding agent in the macro aggregates (Haynes, 2005) [13]. Soil organic carbon (SOC) pools including hot water-soluble organic C (HWOC), microbial biomass C (MBC), water-extractable organic C (WEOC), mineralizable organic C (Cmin), potassium permanganate oxidizable organic C (KMinO4-C), and the oxidizable fractions of decreasing oxidizability (easily-oxidizable, oxidizable, and weakly oxidizable) were investigated as sensitive parameters to the application of organic manure, rice CR, and inorganic fertilizer nitrogen (N) in an 11-year field experiment under rice-wheat system by Benbi et al. (2015) [3]. WEOC exhibited a relatively greater sensitivity to management than TOC, suggesting that it may be used as a sensitive indicator of management-induced changes in soil organic matter under rice-wheat system. Long-term applications of farmyard manure and rice CR resulted in build-up of labile pool of SOC, suggesting the need for continued application of organic amendments for permanence of the accrued C under the experimental conditions. WEOM is a natural part that records for a little segment on soil natural issue (SOM), furthermore, is made out of effortlessly degradable particles that speak to the fundamental C and vitality hotspot for the soil microbial network (Smolander and Kitunen, 2002; Kaiser and Kalbitz, 2012) [28,14]. WEOM is in this manner the most powerful and bioavailable division of the SOM (McDowell, 2003) [23] and usually considered as a marker of microbial movement (Gutiérrez-Girón et al., 2015) [11]. Availability of N in soil is closely associated with both quality and quantity of SOC (Singh et al., 2007) [27]. Ghani et al. (2013) [10] have revealed that the HWEOM-C being a part of the labile SOM and
its association with other labile portions of SOM, for example, microbial biomass-C, water dissolvable C, extractable sugars and mineralisable-N. Furthermore, it has been firmly identified with soil microbial biomass and small-scale conglomeration could in this manner be utilized as one of the soil quality markers in soil–plant biological systems. Characterizing the carbon and nitrogen content of labile organic matter fractions could indicate changes of soil quality due to management practice more rapidly than measuring changes in the magnitude of the whole SOM pool (Ding et al., 2006; Kanchikermath and Singh, 2001) [7, 19]. It can be vulnerable to microbial degradation because of low chemical recalcitrance of its components, lack of physical protection inside soil aggregates (Krull et al., 2003) [17]. Manure application, even once per year, constantly prompted higher augmentations in both SOC and microbial pools and the mixes of concoction manures with compost by and large indicated practically identical impacts in the long-term experiments (Nayak et al., 2012) [24], Abrol et al. (2000) [1] have attributed the declining design in alter productivity of the rice-based cropping sequence in IGP to the declining C stock in soil. The maintenance of SOM with special reference to SOM quality is therefore extremely important for supplying essential plant nutrients and enhancing soil quality (Ladha et al., 2003) [18]. Soil organic carbon quality can be defined as the ability of organic carbon to supply organic molecules and to release carbon dioxide through metabolic pathways, which implies that low quality organic carbon corresponds to organic carbon molecules that needed high number of enzymatic steps to release CO₂ (Wiaux et al., 2013) [33]. In short-term, nutrient cycles, especially labile forms of SOM play an important role (Tisdall and Oades, 1982) [31] which indicate changes in soil quality due to management practices more rapidly than measuring changes in the magnitude of total SOC (Ding et al., 2006) [7]. Soil microbial biomass C and water-soluble C is considered to be important SOM quality parameters because of their faster recycling causing release of nutrients (Janzen et al., 1992; Manna et al., 2013) [13, 21]. Though many studies throughout the world were able to identify appropriate management practices which enhance soil quality (Andrews et al., 2004; Bhaduri et al., 2014; Biswas et al. et al., 2017; Karlen et al., 1994) [2, 4, 5, 16], there is a lack of scientific information on SOM quality-based management systems influencing crop productivity. Changes in soil management practices influence the amount, quality and turnover of soil organic matter (Tiessen and Stewart, 1983) [30].

With this background the All India Coordinated Research Project on Integrated Farming System located in Ludhiana (Inceptisol), Ranchi (Alfisol), Jabalpur (Vertisol) and Pantnagar (Mollisol) with rice-wheat cropping system and maize wheat cropping system at Ranchi (Alfisol) in 0–15 cm and 15–30 cm soil depth was used for this study with the hypothesis that long-term application of carbon and nutrients through either FYM, greenmanure or crop residues in combination with chemical fertilizer having distinct effects on the more labile fraction of SOM in soils with varying soil order, texture and climatic conditions for soils. The objective of present study was to determine the level of changeable soil parameters (i) Hot water extractable organic matter C and N (WEOM-C, WEOM-N) in four soil types of India as influenced by long-term management practices over thirty-two years period (1983–2015).

2. Materials and methods

2.1 Experimental site

All India Coordinated Research Project (AICRP) on Long-term Fertilizer Experiment (LTFE) was initiated in 1983 at the experimental farm located in Pantnagar (Mollisols), Ludhiana (Inceptisols), Jabalpur (Vertisols) and Ranchi (Alfisols) with rice-wheat cropping system for all the locations except Ranchi having maize-wheat cropping system in Integrated Farming System (IFS) coordinated by IIFSR, Modipuram, India was used for the present study. Initial characteristics of the soil has been shown in Table 1. Ludhiana is situated in Punjab and is located at 30°56’S, 75°52’E and 247 m above mean sea level (m.s.l.) The climate of Ludhiana is semi-arid subtropical with hot dry summers and cool winters. Average annual rainfall is 500 mm and potential evapotranspiration 1500 mm. Pantnagar is located at 29°N, 79°5’E and 244 m above m.s.l. in the foot hills of Shivalik range of the Himalayas. Climatically, the area is sub-humid tropical with hot humid summers and severe cold winters. Average annual rainfall is about 1350 mm. Jabalpur is situated in central Madhya Pradesh and is located at 23°90’N latitude, 79°58’E longitude and 411.8 m above m.s.l. Jabalpur lies in subtropical regions thus, it enjoys the features of dry and sub humid climate. Climatically, the area is sub-humid subtropical average annual rainfall is about 1350 mm. Ranchi is located at 23°30’N, 85°15’E and 120 m above m.s.l. This area has sub-humid climate with severe hot, dry summer and cool winter. Average annual rainfall is about 1450 mm.

![Table 1: Initial characteristics of the experimental soils](http://www.chemijournal.com)

| Properties | Ludhiana | Pantnagar | Jabalpur | Ranchi |
|------------|----------|-----------|----------|--------|
| Sand       | 54.0     | 32.0      | 28.0     | 55.0   |
| Silt       | 28.0     | 39.0      | 19.0     | 22.0   |
| Clay       | 18.0     | 29.0      | 53.0     | 23.0   |
| Texture (USDa) | Sandy loam | Silty Clay loam | Clay | Sandy clay loam |
| pH (1:2.5) | 8.15     | 7.3       | 7.54     | 6.5    |
| EC (dSm⁻¹) | 0.32     | 0.35      | 0.48     | 0.10   |
| Organic C (g kg⁻¹) | 3.1     | 14.2      | 6.0      | 4.2    |
| Available N (kg ha⁻¹) | 143.0 | 280.0     | 238.0    | 255.0  |
| Available P (kg ha⁻¹) | 11.0   | 14.5      | 8.6      | 14.2   |
| Available K (kg ha⁻¹) | 101.0  | 120.0     | 287.0    | 195.0  |

2.2. Experimental design

The treatments represented different combinations of inorganic and organic sources of nutrients to rice and wheat. Recommended Fertilizer Dose of different crops in the selected sites has been shown in Table 2. In rice, the full recommended levels of N, P, and K and 50% of N were
supplemented through FYM, (CR) crop residue (wheat CR in Ludhiana, Pantnagar and Jabalpur; paddy CR in Ranchi) and green manuring crops like Sesbania (Sesbania aculeata L. in Ludhiana), Green gram (Vigna radiata L. in Pantnagar), Sunhemp (Crotalaria juncea L. in Jabalpur), Karanj (Pongamia pinnata L. in Ranchi). Of the 12 treatments, five selected for the present study shown in Table 3.

Table 2: Recommended Fertilizer Dose of different crops in the selected sites

| Location/soil type       | Cropping system                  | 100% recommended fertilizer dose (kg ha⁻¹) |
|--------------------------|----------------------------------|------------------------------------------|
|                          |                                  | N | P | K | ZnSO₄₂⁻ |
| Ludhiana (Inceptisol)    | Rice (Oryza sativa L.), cv. PR-116 (Wet season) | 120 | 30 | 30 | 60 |
|                          | Wheat (Triticum aestivum L.), cv. PBW-343 (Winter season) | 120 | 60 | 30 | -   |
| Pantnagar (Mollisol)     | Rice (Oryza sativa L.), cv. PR-113 (Wet season) | 120 | 40 | - | -   |
|                          | Wheat (Triticum aestivum L.), cv. PBW-343 (Winter season) | 120 | 40 | - | -   |
| Jabalpur (Vertisol)      | Rice (Oryza sativa L.), cv. MR-219 (Wet season) | 120 | 60 | 40 |    |
|                          | Wheat (Triticum aestivum L.), cv. GW-273 (Winter season) | 120 | 60 | 40 |    |
| Ranchi (Alfisol)         | Maize (Zea mays L.), cv. M-9000(Wet season) | 100 | 22 | 21 | -   |
|                          | Wheat (Triticum aestivum L.), cv. DCR-162 (Winter season) | 100 | 22 | 21 | -   |

† Applied to all plots once in every three years before rice crop. ¶ Phosphorus treatment included since wet season of the year 2000.

Table 3: Season wise treatment details

|                           | Wet season (Kharif)                      | Winter season (Rabi)                      |
|---------------------------|-----------------------------------------|-----------------------------------------|
|                           | No fertilizer, no organic manure(control) | No fertilizer, no organic manure (control) |
| T₁                        | 100% rec. NPK dose through fertilizers  | 100% rec. NPK dose through fertilizers  |
| T₂                        | 50% rec. NPK dose through fertilizers+ 50% N through FYM (farmyard manure) | 100% rec. NPK dose through fertilizers  |
| T₃                        | 50% rec. NPK dose through fertilizers+ 50 N through CR (CR) | 100% rec. NPK dose through fertilizers  |
| T₄                        | 50% rec. NPK dose through fertilizers+ 50% N through GM (green manure) | 100% rec. NPK dose through fertilizers  |

2.3. Soil sampling

Soil samples were collected to a depth of 0–15 cm and 15-30 cm from the respective plots with the help of core sampler in the year 2015. Samples were obtained after removing plant debris from the soil surface. Immediately after collection, the soil samples were brought to the laboratory; air dried, ground, and passed through a 2-mm sieve for estimation of HWEOM-C and HWEOM-N. The moisture content in soil samples was determined after drying the soil at 105 °C in an oven for 24 h. Soil bulk density was calculated from weights of total field moisture soil, an oven-dried (105 °C, 24 h) sub-sample and the volume of the core sampler following the method of Veihmeyer and Hendrickson (1948) [32].

2.4. Soil organic matter (SOM) pools

2.4.1. Hot water extractable organic matter C (HWEOM-C)

The extraction of HWEOM-C was determined following the procedure of Ghani et al. (2003) [9] in two simple steps. The first step involved removal of readily soluble C (HWEOM-C-I) from the soils that may have come from organic manures and soluble plant residues. The second step involved extraction of labile components of soil carbon at 80 °C for 16 h. This is subsequently referred to as hot-water extractable carbon (HWEOM-C-II). Soil samples (equivalent 3 g oven dry weight) were weighed into 50 ml polypropylene centrifuge tubes. These were extracted with 30 ml of distilled water for 30 min on an end-over-end shaker at 30 rpm and at 20 °C, centrifuged for 20 min at 3500 rpm and all the supernatant from was filtered through 0.45 mm cellulose nitrate membrane filter into separate vials for carbon analysis. A further 30 ml of distilled water was added to the sediments in the same tubes. These tubes were shaken on a vortex shaker for 10 s to suspend the soil in the water. The tubes were capped and left for 16 h in a hot-water bath at 80 °C. At the end of the extraction period, each tube was shaken for 10 s on a vortex shaker to ensure that HWEOM-C released from the SOM was fully suspended in the extraction medium. These tubes were then centrifuged for 20 min at 3500 rpm. The supernatants were filtered through 0.45 mm cellulose nitrate membrane filters. Total carbon content in both the first and second extracts was determined by (Snyder and Trogfomyow, 1984) [29] digestion and distillation method.

2.4.2. Hot water extractable organic matter N (WEOM-N)

It was extracted according to Ghani et al. (2003) [9]. In brief, 3g of dry soil was extracted with 30 ml ultra-pure water in a centrifuge tube. The second step involved extraction at 80 °C for 16 h referred to as hot-water extractable nitrogen (HWEOM-N). The HWEOM-N was determined by drying the supernatant in an oven at 60 °C followed by digestion with concentrated H2SO4 and digestion mixture (K2SO4-CuSO4: Se powder – 200:20:1) in a Kjeltech digestion assembly (Pelican make, Kelplus, model) at 390 °C until the mixture was clear followed by distillation and absorbing the distillate in boric acid mixed indicator in Kjeltech distillation assembly (Pelican make, Kelplus model) followed by titration with standard H2SO4.

3. Results

3.1. Hot water extractable organic matter C and N (HWEOM-C I, HWEOM-C II and HWEOM-N)

In the soils of Ludhiana, it was observed that the HWEOM-C I in 0–15 cm soil samples showed significant variations among the treatments (Table 4). The HWEOM-C I was highest (0.127 mg g⁻¹ and 0.12 mg g⁻¹) in T3 (50% NPK+50%N-FYM) and T5 treatment (50% NPK+50%N-GM), respectively followed by T2 (100% NPK) and T4 (50% NPK+50%N-CR). The HWEOM-C II was highest (0.23 mg g⁻¹, 0.22 mg g⁻¹ and 0.20 mg g⁻¹) in T5 treatment (50% NPK+50%N-GM), HWEOM-N varied significantly in 0–15 cm soil samples among the treatments (Table 4). Increase of HWEOM-N in T5 and T3 were 3.79 and 3.15 times over T1 (control) respectively. The treatment

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T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.35 and 1.78 times increase in WEOM-N over control. In 15-30 cm, HWEOM-C I was highest (0.127 mg g⁻¹) and 0.12 mg g⁻¹ in T3 (50%NPK+50%N-FYM) and T5 treatment (50%NPK+50%N-GM), respectively. T2 (100%NPK) and T4 (50%NPK+50%N-CR) were at par with respect to HWEOM-C I. The HWEOM-C II was highest in T5 treatment (50%NPK+50%N-GM) and T3 (50%NPK+50%N-FYM) which were at par followed by T4 (50%NPK+50%N-CR) and T2 (100%N PK), respectively. The increase of HWEOM-N in T5 and T3 were 4.5 and 3.8 times over T1 (control) respectively. The treatment T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.66 and 2.16 times increase in HWEOM-N over T1.

Table 4: Long term effect of manuring and fertilization on hot water extractable C and N (HWEOM-C I, II and N) (in mg g⁻¹) in 0-15 cm and 15-30 cm soils of Ludhiana.

| Treatments | HWEOM-N | HWEOM-C I | HWEOM-C II | HWEOM-N | HWEOM-C I | HWEOM-C II |
|------------|---------|-----------|------------|---------|-----------|------------|
| T1-Control | 0.015e  | 0.030c    | 0.047c     | 0.117e  | 0.033c    | 0.040d     |
| T2-100%NPK | 0.026d  | 0.077b    | 0.123b     | 0.026d  | 0.070b    | 0.087c     |
| T3-50%NPK+50%N-FYM | 0.036c | 0.127a | 0.223a | 0.043b | 0.127a | 0.183a |
| T4-50%NPK+50%N-CR | 0.048b | 0.067b | 0.200a | 0.032c | 0.053c | 0.143b |
| T5-50%NPK+50%N-GM | 0.058a | 0.120a | 0.230a | 0.054a | 0.120a | 0.186a |

§The data followed by different lowercase letters are significant according to Duncan’s Multiple Range (DMRT) Test at 5% level of significance. Values in the same column followed by different lowercase letters (a–e) are significantly different at P=0.05 according to Duncan’s Multiple Range Test.

In the soils of Pantnagar, HWEOM-C I was highest (0.157 mg g⁻¹) in T3 (50%NPK+50%N-FYM). T5 treatment (50%NPK+50%N-GM) and T2 (100% NPK) both shows non-significant variation followed by T4 (50%NPK+50%N-CR). HWEOM-C II was highest (0.256 mg g⁻¹) in T3 (50%NPK+50%N-FYM). All treatments showed increase in HWEOM-C II over control. HWEOM-N was highest in T5 treatment (50%NPK+50%N-GM) followed by T3 (50%NPK+50%N-FYM), T4 (50%NPK+50%N-CR) and T2 (100 NPK) respectively and the increase of HWEOM-N in T5 and T3 were 3.24 and 2.53 times over T1 (control) respectively. The treatment T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.23 and 1.53 times increase in WEOM-N over T1 (Table 5).

It was observed that the HWEOM-C I in 15-30 cm soil samples didn’t show much significant variation among the treatments. HWEOM-C I was highest (0.107 mg g⁻¹) in T3 (50%NPK+50%N-FYM) and T5 treatment (50%NPK+50%N-GM). T2 (100% NPK) and T4 (50%NPK+50%N-CR) were at par. HWEOM-C II was highest (0.207 mg g⁻¹) in T3 (50%NPK+50%N-FYM). T5 treatment (50%NPK+50%N-GM) and T2 (100 NPK) both shows non-significant variation followed by T4 (50%NPK+50%N-CR). HWEOM-N varied significantly in 15-30 cm soil samples among the treatments. The increase of HWEOM-N in T5 and T3 were 3.78 and 2.76 times over T1 (control) respectively. The treatment T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.23 and 1.65 times increase in WEOM-N over T1 (Table 5).

Table 5: Long term effect of manuring and fertilization on hot water extractable C and N (HWEOM-C I, II and N) (in mg g⁻¹) in 0-15 cm and 15-30 cm soils of Pantnagar.

| Treatments | HWEOM-N | HWEOM-C I | HWEOM-C II | HWEOM-N | HWEOM-C I | HWEOM-C II |
|------------|---------|-----------|------------|---------|-----------|------------|
| T1-Control | 0.02c   | 0.02c     | 0.07d      | 0.01e   | 0.026c    | 0.04a      |
| T2-100%NPK | 0.03d   | 0.06b     | 0.16b      | 0.03d   | 0.043c    | 0.12b      |
| T3-50%NPK+50%N-FYM | 0.05b | 0.16a | 0.26a | 0.05c | 0.106a | 0.21a |
| T4-50%NPK+50%N-CR | 0.04c | 0.03c | 0.13c | 0.04b | 0.06b | 0.09c |
| T5-50%NPK+50%N-GM | 0.06a | 0.08b | 0.18b | 0.06a | 0.106a | 0.15b |

§The data followed by different lowercase letters are significant according to Duncan’s Multiple Range (DMRT) Test at 5% level of significance. Values in the same column followed by different lowercase letters (a–e) are significantly different at P=0.05 according to Duncan’s Multiple Range Test.

In the soils of Jabalpur, HWEOM-C I in 0-15 cm soil samples showed significant variation among the treatments (Table 6). HWEOM-C I was highest (0.347 and 0.197 mg g⁻¹) in T3 (50%NPK+50%N-FYM) followed by T2 (100% NPK). HWEOM-C II in 0-15 cm soil samples showed significant variation among the treatments. HWEOM-C II was highest (0.447 mg g⁻¹) in T3 (50%NPK+50%N-FYM) followed by T2 (100%NPK), T4 (50%NPK+50%N-CR) and T5 treatment (50%NPK+50%N-GM) respectively. All treatments showed increase in HWEOM-C II over control. HWEOM-N was highest in T5 treatment (50%NPK+50%N-GM) followed by T3 (50%NPK+50%N-FYM), T4 (50%NPK+50%N-CR) and T2 (100% NPK) respectively and the increase of HWEOM-N in T5 and T3 were 3.37 and 2.78 times over T1 (control) respectively (Table 6).

HWEOM-C I in 15-30 cm soil samples showed significant variation among the treatments. HWEOM-C I was highest (0.267,0.150 and 0.093 mg g⁻¹) in T3 (50%NPK+50%N-FYM) followed by T2 (100% NPK), T4 (50%NPK+50%N-CR) respectively. HWEOM-C II in 15-30 cm soil samples showed significant variation among the treatments. HWEOM-C II was highest (0.400 mg g⁻¹) in T3 (50%NPK+50%N-FYM) followed by T2 (100%NPK), T4 (50%NPK+50%N-CR) and T5 treatment (50%NPK+50%N-GM) respectively. All treatments showed increase in HWEOM-C II over control. HWEOM-N in T5 and T3 were 4.30 and 2.90 times over T1 (control) respectively. The treatment T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.66 and 2.16 times increase in WEOM-N over T1 (Table 6).
In soils of Ranchi, HWEOM-C I in 0-15 cm was highest (0.137±0.093 and 0.063 mg g⁻¹) in T3 (50%NPK+50%N-FYM) followed by T5 treatment (50%NPK+50%N-GM), T4 (50%NPK+50%N-CR) and T2 (100% NPK) respectively. All treatment showed increased HWEOM-C I over control. HWEOM-C II in 0-15 cm soil samples didn’t show much significant variation among the treatments. HWEOM-N varied significantly in 0-15 cm soil samples among the treatments (Table 7). HWEOM-N was highest in T5 treatment (50%NPK+50%N-GM) followed by T3 (50%NPK+50%N-FYM), T4 (50%NPK+50%N-CR) and T2 (100% NPK) respectively and the increase of HWEOM-N in T5 and T3 were 4.77 and 3.49 times over T1 (control) respectively. The treatment T4 (50%NPK+50%N-CR) and T2 (100%NPK) showed 2.60 and 1.60 times increase in WEOC-N over T1.

Table 6: Long term effect of manuring and fertilization on hot water extractable C and N (HWEOM-C I, II and N) (in mg g⁻¹) in 0-15 cm and 15-30 cm soils of Jabalpur.

| Treatments       | HWEOM-N  | HWEOM-C I | HWEOM-C II | HWEOM-N  | HWEOM-C I | HWEOM-C II |
|------------------|----------|-----------|------------|----------|-----------|------------|
|                  | 0-15 cm  | 15-30 cm  | 0-15 cm    | 15-30 cm | 0-15 cm   | 15-30 cm   |
| T1-Control       | 0.017c   | 0.06d     | 0.14c      | 0.01a    | 0.013c    | 0.1e       |
| T2-100% NPK      | 0.03d    | 0.19b     | 0.20d      | 0.02d    | 0.043d    | 0.25b      |
| T3-50%NPK+50% N-FYM | 0.03c   | 0.34a     | 0.23c      | 0.043b   | 0.120a    | 0.40a      |
| T4-50%NPK+50% N-CR | 0.04b   | 0.15c     | 0.29b      | 0.034c   | 0.057c    | 0.19c      |
| T5-50%NPK+50% N-GM | 0.05a   | 0.13c     | 0.44a      | 0.064a   | 0.077b    | 0.106e     |

Table 7: Long term effect of manuring and fertilization on hot water extractable C and N (HWEOM-C I, II and N) (in mg g⁻¹) in 0-15 cm and 15-30 cm soils of Ranchi.

| Treatments       | HWEOM-N  | HWEOM-C I | HWEOM-C II | HWEOM-N  | HWEOM-C I | HWEOM-C II |
|------------------|----------|-----------|------------|----------|-----------|------------|
|                  | 0-15 cm  | 15-30 cm  | 0-15 cm    | 15-30 cm | 0-15 cm   | 15-30 cm   |
| T1-Control       | 0.012e   | 0.043b    | 0.097c     | 0.008e   | 0.013e    | 0.023a     |
| T2-100% NPK      | 0.020d   | 0.05d     | 0.080b     | 0.019d   | 0.043d    | 0.067b     |
| T3-50%NPK+50% N-FYM | 0.043b | 0.13a     | 0.213a     | 0.039b   | 0.120a    | 0.170a     |
| T4-50%NPK+50% N-CR | 0.032c   | 0.063c   | 0.077b     | 0.029c   | 0.057c    | 0.04ab     |
| T5-50%NPK+50% N-GM | 0.059a   | 0.093b   | 0.113b     | 0.055a   | 0.077b    | 0.070b     |

4. Discussion

Our study clearly demonstrated that the Hot water extractable carbon (HWEOM-C I, II) was highest in 50%NPK+50%N-FYM in both the soil depths for Mollisol, Vertisol and Alfisol but in Inceptisol HWEOM-C I was highest in 50%NPK+50%N-FYM and HWEOMC-II in 50%NPK+50%N-GM in both the soil depths (Fig.1). Hot water extractable nitrogen (HWEOM-N) was highest in 50%NPK+50%N-GM for all soil orders in both the soil depths. The hot water extractable carbon (HWEOM-C) showed variable results across different soils. The 50%NPK+50%N-GM in Inceptisol and Vertisol and 50%NPK+50%N-FYM FYM in Alfisol and Mollisol showed higher amount of HWEOM-C. The HWEOM-C might be representing different fractions of moderately resistant pool of carbon which is not extracted by cold water. Therefore, in FYM treated soil showed relatively higher amount of HWEOM-C than the other treatments. Besides this, the soil type and different green manuring crops with different biochemical recalcitrance might have played a greater role especially in Inceptisol and Vertisol. The increase in water soluble C with application of inorganic N fertilizers could be as a result of the priming effect of applied inorganic N on fresh organic material in the soil which stimulates the microbial activity helping in the decomposition of SOM with rapid release of the DOC fraction (Leon et al., 2015) [19]. Contrarily, Sharma et al. (2017) [26] reported that GM management resulted in (i) a substantial increase in dissolved organic C concentration, (ii) GM-HWEOM becoming enriched by hydrophilic aliphatic organic compounds. It is quite obvious that green manuring crops richer nitrogen content and narrower in C: N might contribute more towards easily degradable part of organic matter unlike other materials like CR or FYM. The beneficial effect of FYM application under rice-wheat cropping system on DOC content was also reported by others (Manna et al., 2005, Brat et al., 2013) [22,26]. After 11 years of experiment, there was improvement in WOEC, HWOC, KmnO₄-C, easily-oxidizable fraction, Cmin, and MBC by applications of farmyard manure and rice CR. During the 11-year period, the greatest increase was observed in WOEC and the minimum in KmnO₄-C. All other labile SOC pools had the same sensitivity to management as TOC. Most of the SOC pools were positively correlated to each other though their amounts differed considerably (Benbi et al., 2015) [3].
Majumder et al. (2007) \cite{20} also have reported the components of SOC pools viz., signify normal carbon, oxidisable regular carbon and its four particular segments, for instance, to a great degree labile, labile, less labile and non-labile carbon, microbial biomass carbon, mineralizable carbon, and particulate common carbon in association with varying productivity using a multi-years old rice−wheat−jute cropping sequence with different organization techniques in the hot moist, subtropics of India.

5. Conclusion
As interest increases in both promoting organic C storage, it is crucial to understand the relative sequestration efficiency of added C source as well as its stability in the soil. Optimum levels of soil organic matter (SOM), its labile and recalcitrant pools can be managed through crop rotation, fertility maintenance including use of inorganic fertilizers and organic manures, tillage methods, and other cropping system components. Among these management practices, proper cropping systems and balanced fertilization are believed to offer the greatest potential for increasing SOC storage in agricultural soils. In this regard, 50%NPK+50%N-through organic sources has been proven to be a potent nutrient management practices for enhancing labile pools of SOM like HWEOM-C and N depending upon soil type, climatic condition and management practices. Also being closely related to soil microbial biomass and micro-aggregation, these could therefore be used as one of the soil quality indicators.

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\textbf{Fig 1:} Level of hot water extractable organic matter carbon-I and II (HWEOM-C-I, II) and hot water extractable nitrogen (HWEOM-N) in 0-15 cm soil depth (a) and 15-30cm soil depth (b) as affected by long term fertilization and manuring in four soil types of India.
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