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CAN INTEGRATED NUTRIENT MANAGEMENT SUSTAIN THE SOIL HEALTH

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ABSTRACT

Introduction of advanced agricultural technologies along with release of high yielding varieties of cereals made us able to attain self-sufficiency but this trend leads to increased demand for fertilizers and other inputs. Inspite of this, there is a declining response of yield to fertilizers and this could be attributed to the decline in organic matter content, imbalanced use of fertilizers, over mining of soil nutrients, low use of organic manures, deficiency of secondary and micronutrients. To arrest this fall in soil productivity, there is urgent need to revive the age old practice of farmyard manure application (FYM) or other bio-degradable farm wastes along with mineral fertilizers for maintenance of soil health to supplement essential plant nutrients, including micronutrients. Addition of organic matter enhances soil health which in turn improves soil physical, chemical and biological properties of soil and makes us to survive in future as we know world population and food production demands is going to rise in future, keeping our soil healthy and productive is thus of paramount importance. Thus, this paper reviews the role of integrated nutrient management that could possibly sustain the soil health to achieve us the target of sustainable agriculture.

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INTRODUCTION

'Soil health' is defined as being a state of dynamic equilibrium between flora and fauna and their surrounding soil environment in which all the metabolic activities of the former proceed optimally without any hindrance, stress or impedance from the latter (Goswami and Rattan, 1992). Soil health is considered as the state of a soil at a particular time, equivalent to the dynamic soil properties that change in short-term, while soil quality may be considered as soil usefulness for a particular purpose over a long time scale, equivalent to intrinsic or static soil quality (Goswami, 2006). Soil Health is "the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al.*, 1997). Thus there are several definations given by different scientists but all comes to single point conclusion.

Productivity of crops by soil depends upon the soil health which is decided by the physical, chemical and biological properties of soil. Due to intensive cropping, where food grain production and fertilizer use run parallel, soil is degrading day by day with respect to soil fertility and productivity. This may be attributed to the minimum and extra removal of nutrient resources from the soil strata than they are replenished, so soil is becoming deficient in available nutrients. Since, agriculture becomes more intensive and chemical dependent, therefore soil toxicities and nutrient imbalance threaten sustainable production. Indiscriminate use of chemical fertilizers to get maximum yields leads to the depletion of inherent soil fertility (Gupta and Nath, 1998). Use of organic matter such as animal manures, human waste, food wastes, yard wastes, sewage sludges and composts has long been recognized in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility. Secondly, the demand for fertilizers can be lowered by supplementing the nutrients through organic manures. Judicious use of FYM with chemical fertilizers improves soil physical, chemical and biological properties and improves the crop productivity (Sharma *et al.* 2007). Application of organic manures may also improve availability of native nutrients in soil as well as the efficiency of applied fertilizers (Sawrup, 2010). Patil *et al.* in 2016 conducted a field experiment during *rabi* season consequently for three years to study the INM in carrot. Among the different treatments, the application of 50% RDF + 25% N through FYM + 25% N through vermicompost recorded significantly higher root yield of carrot (24.10 t ha^{-1}) compared to rest of the treatments. After three years of experiments on same site, combined usage of organic manure with inorganic fertilizers is not only help to improve the yield of carrot but also help in conserving the soil health.

The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. Organic matter are excellent source of plant-available nutrients and their addition to soil could maintain high microbial populations and activities with increased values of biomass C, basal respiration, biomass C: total organic C ratio, and metabolic quotient (qCO_2).

Sekhon *et al.* (2011) reported that application of mineral fertilizers, alone or in

combination with organic manures for led to a marked increase in total N, hydrolysable N (amino acid-N, amino sugar-N, ammonia-N, hydrolysable unknown-N) and non-hydrolysable N compared with their original status in soil. In an another field experiment, conducted during Kharif 2006-07 and 2007-08 to demonstrate the effect of combined application of organic and mineral fertilizer on the available nutrient status of soil, ten integrated management modules were evaluated under Mollisols of Tarai region. From the results obtained it was observed that the treatment consisting of both organic and inorganic nutrient sources performed best among all the treatments used in the experiment (Singh *et al*., 2015). Understanding the effect of fertilizer nitrogen and organic amendments on the interplay between different forms of organic N is a prerequisite for managing N inputs in a given soil and it is also important to optimize the rate of application of organic manures and chemical fertilizers in an integrated nutrient management system to maintain an adequate supply of nutrients for increased yields and reduced environmental pollution. Therefore, the present study deals with the effect of integrated nutrient management on soil health and its role in achieving the target of sustainability.

Effect of integrated nutrient management on soil physical properties

Based on data from 12 different sources, 21 soil types, 7 organics, and 8 crops, Khaleel *et al*. (1981) observed a linear regression analysis of observed increases in soil organic carbon as a result of organic waste applications on per cent reduction in bulk density (r = 0.69**). The results of an exponential multiple regression analysis of percentage sand and increase in organic carbon percentage on the increase in water holding capacity indicated that approximately 80% of the observed variations in increase in water holding capacity, at both field capacity and wilting point, could be attributed to variations in soil texture and soil organic carbon increase. Lax and Garcia-Orenes (1993) reported that addition of organic matter to soil increased the number and size of water stable macro-aggregates. Acharya *et al*. (1988) also reported the beneficial effect of long term application of balanced dose of chemical fertilizers singly or in combination with organic manures on formation of large size aggregates in Alfisols. Aggelides and Londra (2000) concluded that porosity and water retention capacity of loamy and clayey soils increased with application of compost. Aggelides and Londra (2000) concluded that porosity and water retention capacity of loamy and clayey soils increased with application of compost. Hudson (1994) observed that soils high in organic matter had greater water available to plants than the soils of similar texture reported highest. Celik *et al*. (2004) mean weight diameter of soil aggregates increased under the manure treatment while total porosity and saturated hydraulic conductivity decreases. Soil organic matter affects infiltration through its positive effect on the development of stable soil aggregates, or crumbs. Highly aggregated soil has increased pore space and infiltration.

Farmyard manure significantly influenced the soil organic matter concentration (%) in soil as compared to application of recommended NPK dose. Farmyard manure enhanced the water retention capacity of soil which might be ascribed to the micropores while high rate of water transmission may be associated with the macro-pores of soil as influenced by high organic carbon and better soil aggregation (Mishra and Sharma, 1997). The increase in water retention as a result of FYM application is expected from the aggregation resulting in favorable pore geometry of the soil (Bhattacharya *et al*. 2004). The increased soil moisture content with combined application of MRP+FYM was attributed to organic manure, which

Table 1: Effect of integrated nutrient management on physical properties of soil

Treatments	Physical properties				
	Bulk density (Mg m^{-3})	Field capacity (%)	Permanent wilting point (%)	Hydraulic conductivity (cm hr^{-1})	Infiltration rate (cm hr^{-1})
Control	1.37	39.45	26.07	1.34	0.91
100 % RDN	1.38	39.49	26.23	1.32	0.90
100 % RDN through VC	1.34	40.82	25.10	1.67	1.03
75 % RDF + 25 % RDN through VC	1.36	39.75	26.05	1.43	0.94
50 % RDF + 50 % RDN through VC	1.35	39.82	25.29	1.54	0.95
25 % RDF + 75 % RDN through VC	1.34	40.52	24.87	1.57	0.99
CD at 5 %	NS	0.9	0.3	0.03	0.03

Source: Gudadhe *et al*., 2015

Table 2: Changes in soil organic carbon (SOC), SOC pool and carbon sequestration rate after 36 years of different fertilizer applications in maize-wheat rotation

Treatments	SOC (g kg^{-1})			SOC pool (Mg ha^{-1})			SOC sequestrationrate (kg $ha^{-1}yr^{-1}$)
	1971	2007	Change	1971	2007	Change	
Control	2.55a	3.08b	0.53c	6.10a	7.30d	1.20e	33e
50% NPK	2.38a	3.57ab	1.19bc	5.70ab	8.40bc	2.70de	75d
100% NPK	2.08a	3.71ab	1.63b	5.00c	8.70b	3.70bc	103bc
100% NPK + Zn	2.23a	3.69ab	1.46b	5.30b	8.60bc	3.30bc	92b
100% NPK + FYM	2.03a	5.20a	3.17a	4.90c	11.60a	6.70a	186a

Source: Brar *et al*., 2015

Table 3: Effect of integrated nutrient management on chemical properties of soil

Treatments	Chemical properties Organic carbon (%)	Available nutrients (kg ha^{-1}) N	P	K
Control	0.43	71.7	20.43	290.8
100 % RDN	0.49	108.7	23.48	293.0
100 % RDN through VC	0.69	103.7	14.48	297.6
75 % RDF + 25 % RDN through VC	0.55	117.0	26.40	309.7
50 % RDF + 50 % RDN through VC	0.63	112.7	17.19	301.9
25 % RDF + 75 % RDN through VC	0.64	103.8	15.31	299.2
CD at 5 %	0.03	4.8	2.26	6.00

Source: Gudadhe *et al.*,2015

Table 4: Effect of INM on phosphatase activity (ig P nitrophenol/g soil/h) in soil

Treatment	Vegetative stage	Flowering stage	Harvest stage
Control	194.7	244.2	104.5
100% RDNF	235.8	294.0	132.8
100% VC	212.2	265.5	115.0
75% N+25% VC	246.7	308.2	138.7
50% N+50% VC	233.7	286.8	125.3
C. D. (P=0.05)	4.92	7.41	4.56

VC–Vermicompost and PM–Poultry manure; Source: Chaitanya *et al.*, 2013

Table 5: Effect of INM on Urease activity (ig NH_4^+-N released/5 g soil/2 h) in soil

Treatment	Vegetative stage Acid phosphatase	Alkalin ephosphatase	Flowering stage Acid phosphatase	Alkalin ephosphatase	Harvest stage Acid phosphatase	Alkalin ephosphatase
Control	20.56	45.63	34.66	67.57	16.35	52.78
100% RDNF	24.30	52.68	39.80	77.75	19.65	58.91
100% VC	34.93	64.43	48.30	88.54	25.37	70.25
75% N+25% VC	28.63	57.39	42.87	81.39	21.48	63.97
50% N+50% VC	31.75	58.85	45.97	84.80	22.55	67.38
C. D. (P=0.05)	1.13	1.38	0.76	1.17	0.85	1.48

VC–Vermicompost and PM–Poultry manure; Source: Chaitanya *et al.*, 2013

contributed to the maintenance of soil physical structure and resulted in better soil moisture retention. Use of organic amendments, like FYM, vermicompost, microbial consortia and organic mulching are effective means for enhancing soil fertility, microbial diversity and population, microbial activity, improving the soil physical properties particularly moisture holding capacity of soils and increasing crop yields (Adak *et al.*, 2013). Organic matters not only increase the water holding capacity of the soil but also the portion of water available for plant growth and improve the soil physical properties (Sial *et al.*, 2007). The reduction in bulk density of the soil might be due to the increase in humic substances which further resulted in increased porosity and water holding capacity of soil (Babulkar *et al.,* 2000). Gudadhe *et al*. (2015) conducted a experiment to study effect of integrated nutrient management on soil properties under cotton-chickpea cropping sequence in vertisols of Deccan plateau of India. Results showed that Application of Recommended Dose of Fertilizer (RDF) according to Soil Test Crop Response (STCR) equation recorded significantly higher seed cotton yield and cotton equivalent yield, however it was at par with 10 t Farm Yard Manure (FYM) ha^{-1} + RDF. The soil physical properties determined at the end of two crop cycles were improved due to the application of manures in sole or in combination with chemical fertilizers (Table 1).

Effect of integrated nutrient management on soil chemical properties

Maskina *et al*. (1988) reported that use of FYM improved the general soil productivity by increasing soil organic carbon and available nutrients. Sharma and Mittra (1990) also reported marked improvement in organic carbon and available N, P and K in FYM amended plots in rice-wheat rotation. The combined application of FYM and chemical fertilizers to soil in rice-wheat rotation increased the available N, P and K status of soil and also improved its organic carbon content (Brar *et al.*, 1995). Similarly, Dhiman *et al*. (1999) reported that organic carbon, available P and K were highest wherein additional FYM application was made. The application of FYM with inorganic fertilizers was more effective as compared to inorganic fertilizers alone in building up soil fertility status (Bajpai *et al.*, 2002). Application of FYM increased SOC, and it also exacerbates N_2O emissions (Jones *et al*. 2007). Based on the comprehensive consideration of soil fertility, environment and crop yields, the combined application of FYM and INF is a sustainable soil management option for the wheat-maize cropping system in the North China plain. Several studies indicated that long-term and balanced application of chemical fertilizers and organic manure can generally achieve higher crop yields and improve soil quality than any of these applied alone (Rudrappa *et al.,* 2006; Manna *et al.,* 2007;

Table 6: Effect of different nutrient management on biological properties of soil

Treatment	Fungi(10^4/g)	Bacteria(10^6/g)	PSB(10^6/g)	Actinomycities(10^6/g)
Control	33.7	35.7	9.7	5.9
100% organic	49.3	60.0	20.5	14.5
100% inorganic	38.8	36.1	12.4	7.9
Integrated (50% each of organic and inorganic)	41.7	44.2	15.5	11.6

Source: Dubey *et al*., 2014

Fan *et al.,* 2008).

Banger *et al*. (2009) observed that a sandy soil amended with FYM contained 36.1% more SOC and 24.4% more total nitrogen than those in the CK in the 0–15 cm depth under a 16 year rice-cowpea cropping system in semi-arid tropics. Similar beneficial effects of FYM on SOC have been observed in other long-term experiments elsewhere (Blair *et al*. 2006b; Yan *et al*. 2007; Simon 2008; Gong *et al*. 2009b). Gopinath and Mina (2011) revealed that the soil organic C was significantly higher in all the treatments (1.21-1.30%) except in poultry manure 5 t ha^{-1} + bio-fertilizers when compared with control (1.06%). Application of farmyard manures 10 t ha^{-1} + recommended NPK, however, recorded significantly higher available N than plots under organic manures. Application of farmyard manure 10 t ha^{-1} + recommended NPK being at par with application of farmyard manure 10 t ha^{-1} + poultry manure and vermicompost and registered significantly higher available P and K contents in soil compared to other treatments.

In general, under intensive cropping, soil organic carbon declined over time (Lal, 1989). Higher levels of organic carbon in the surface soils of the NPK and NPK + FYM treated plots of Mollisols (Bhardwaj and Omanwar, 1994) (Reddy *et al*. 2001) in Vertisols had been reported. Increases in dissolved OC concentration with application of FYM have also been reported by Banger *et al*. (2010) and Gong *et al*. (2009b), probably because the FYM containing decayed soluble SOM (Liang *et al*. 1997). Gudadhe et al. (2015) conducted a experiment to study effect of integrated nutrient management on soil properties under cotton-chickpea cropping sequence in vertisols of Deccan plateau of India. Results showed that Application of Recommended Dose of Fertilizer (RDF) according to Soil Test Crop Response (STCR) equation recorded significantly higher seed cotton yield and cotton equivalent yield; however it was at par with 10 t Farm Yard Manure (FYM) ha^{-1} + RDF. The soil chemical properties determined at the end of two crop cycles were improved due to the application of manures in sole or in combination with chemical fertilizers (Table 3). Brar *et al*. (2015) studied the effects of long term application of inorganic and organic fertilizers on soil organic carbon and reported that the SOC increased with continuous application of FYM and inorganic fertilizers for 36 years among all treatments (Table 2).

Effect of integrated nutrient management on soil biological properties

Application of FYM (12 t ha^{-1}) with 75% NPK improves the fertility status and also recorded higher grain and straw yield of wheat than 100% NPK alone (Singh, 2008 and Ram and Mir, 2006). Application of 100% NPK + FYM (10 t ha^{-1}) recorded significant increase in biological parameters viz. soil microbial biomass carbon (SMBC), soil microbial biomass nitrogen (SMBN) and dehydrogenase activities (DHA) to the extent of 8.8, 9.8 and 9.0 % as compared to 150 % NPK through chemical fertilizers without organics (Katkar *et al*. 2011). Application of NPK and FYM applied soil showed higher microbial biomass in wheat (Majundar *et al*. 2008). Bobulska *et al*. (2008) studied the impact of different farming methods on soil quality and fertility in specific eco-regions. Large differences between the two sites were found in terms of microbiological properties, which are sensitive soil indicators of changes occurred under different farming systems. The study confirmed the positive influence and higher microbial activity indices of ecological farming (36% higher enzymatic activity, 65% higher soil respiration content, 60% higher soil microbial biomass carbon content) compared with conventional farming system. Carine Floch *et al*., (2009) reported that the soil enzyme activities and microbial population are higher in organically managed farming when compared to the conventional and integrated managed farming. In an apple orchard, biological soil properties improved in the organic compared to the conventional management, however, there were few significant differences in soil properties between the integrated and organic systems (Glover *et al*., 2000). Enzymes may respond to changes in soil management more quickly than other soil variables and, therefore, enzymes might be useful as early indicators of biological change (Bandick and Dick, 1999). Organic manures, such as animal manure, green manure, and crop residue, significantly increased the activity of a wide range of soil enzymes, as compared to unamended soil (Martens *et al*., 1994). Chaitanya et al. (2013) studied the activity of soil urease, phosphatase and dehydrogenase as influenced by integrated nutrient management in tomato (*Lycopersicon esculentum* L.) grown on alfisol. Results showed that Significantly highest urease activity of 234.0, 288.8 and 126.7 µg of NH_4^+ -N released/5 g soil/2 h with the combined application of 75% RDNF + 25% VC, significantly highest dehydrogenase activity of 161.0, 177.1 and 133.4 µg of TPF produced/g soil/d, the highest acid phosphatase activity of 35.23, 48.55, 25.55 ìg of PNP released/g soil/h and the highest alkaline phosphatase activity of 65.07, 88.64, 71.27 µg of PNP released/g soil/h were obtained at vegetative, flowering and harvest stages, respectively, with the combined application of 50% VC and 50% PM. All three enzyme activities were increased from the vegetative to flowering stage and later showed decrease from flowering to harvest stage (Table 4 and 5). Dubey *et al*. (2014) studied the Effect of organic, inorganic and integrated nutrient management on crop productivity, water productivity and soil properties under various rice-based cropping systems in Madhya Pradesh, India. He reported that As regards biological properties of soil, the population of microbes such as fungi,

bacteria, azotobacter, PSB and actinomycetes increased remarkably with all cropping systems associated with 100% organic nutrition over their initial status after completion of 4th crop-cycle (Table 6). The values of these microbes declined with integrated nutrient management over 100% organic nutrition, while population of these microbes was minimum under all cropping system with 100% inorganics.

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