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Studies on long term impact of STCR based integrated fertilizer use on pearl millet (*Pennisetum glaucum*)-wheat (*Triticum aestivum*) cropping system in semi arid condition of India

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Abstract

A long term field experiment on pearl millet - wheat cropping system with soil test crop response correlation (STCR) based fertilizer application was initiated during *kharif* - 2003 on a sandy loam soil (Typic Halustept) at a research farm of Indian Agricultural Research Institute, New Delhi. The aim of the experiment was to study the impact of STCR based integrated fertilizer application for targeted yield of pearl millet - wheat cropping sequence yield and changes in soil health. The result showed a significant and positive impact of integrated use of the fertilizer with FYM on productivity of the cropping sequence and soil fertility. The STCR based integrated fertilizer recommendations with FYM produced significantly higher grain and straw yields of pearl millet and wheat crops as compared to other treatments. The highest average (2003 to 2010-11) grain and straw yield of pearl millet (2.85 and 6.59 t ha^{-1}) and wheat (5.32 and 7.17 t ha^{-1}) was recorded with the application of STCR based integrated fertilizer recommendations (T_2) for targeted level of yield 2.5 and 5.0 ha^{-1}, respectively. Average increase in grain and straw yield of pearl millet was 203 and 197 % and 196 and 193 % of wheat under T_2 treatment over control (T_4). After harvest of wheat crops (2010-11), the physical, biological properties and fertility status *i.e.* available N, P and K of soil were improved in the treatments where STCR based integrated fertilizer dose with 10 t FYM (T_2) and FYM @ 20 t ha^{-1} (T_1) were applied in both the crops and were significantly higher as compared to T_3 treatment except available phosphorus. Economic analysis based on average yield of eight cropping sequence (2003 to 2010-11), pearl millet - wheat cropping sequence gave maximum net return of Rs. 1,00,907 ha^{-1} yr^{-1} and total return of Rs. 64,992/ ha^{-1} yr^{-1} over control with STCR based integrated fertilizer recommendations (T_2). It is concluded that STCR based integrated fertilizer can be adopted by the farmers of arid region for getting higher yield, profit and improving soil health.

Key words

Economics, Nutrient, Pearl millet, STCR, Soil characteristics, Wheat

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Introduction

Pearl millet (*Pennisetum glaucum*) - wheat (*Triticum aestivum*) cropping sequence is the most important and popular cropping sequence under irrigated conditions in arid and semi arid regions of India. The major challenge confronting India during 21st century is to produce enough food, fodder, fibre, fuel so as to meet the diversified need of the burgoeing human and animal population of the country. This requirement can be achieved through enhanced productivity of different crops, using improved technology and increased cropping intensity. In this contest, judicious use of plant nutrients is one of the most important aspects to be adopted for sustained production of crops. However, continuous use of high analysis fertilizers accelerated mining of micro and secondary nutrients which brought down the productivity of cropping systems at several places in the country (Singh, 2010). The stagnation in crop production in India is basically due to conventional fertilizer recommendation, low fertilizer use efficiency and imbalanced use of fertilizers. The quantitative evaluation of fertilizer doses may assist in improving yield with simultaneous increase in nutrient use efficiency. Therefore, it was sustained with integrated nutrient supply through organic, bio and inorganic fertilizers. It has also been realized that organic manures can not be complete substitute for chemical fertilizers and vice versa for achieving food and nutritional security the country.

Alternatively, organic manure is a valuable and renewable nutrient source, but its application alone to soils is not adequate to meet the nutrient (nitrogen) demand of the modern varieties of crops and results in poor yield of the crops (Antil and Narwal, 2007). Nevertheless, their regular addition enhances not only the biological activity and diversity but also improves the physical properties of the soil (Kumar and Tripathi, 2009). Therefore, integration of inorganic with organic may go a long way in maintaining sustainable crop production and enhancing soil health through their complementary effects (Yang, 2006) and (Antil *et al*., 2011).

On the other the hand, balanced fertilizer is the application of essential plant nutrients in the right proportion and in optimum quantity for a specific- crop condition. Continuous imbalanced use of fertilizer leads to deterioration soil fertility and decrease soil productivity (Jaga and Upadhyay, 2013). Integrated plant nutrient supply system can help in meeting the goal of balanced fertilization (Chatterjee *et al.,* 2010; Jaga and Upadhyay, 2013). The practice of nutrient application based on STCR fertilizer recommendations for targeted yield using developed fertilizer adjustment equations for crops provides better option for balanced application of nutrients. The present investigation was carried out to study the effect of STCR based fertilizer recommendations on yield, economics and changes in soil properties under pearl millet - wheat cropping sequence.

Materials and Methods

A long term field experiment was initiated in 2003 with pearl millet (*Pennisetum glaucum*) and wheat (*Triticum aestivum*) cropping sequence at the research farm of Indian Agricultural Research Institute, New Delhi. The experimental site is situated at latitude 28º30'N and longitude 77º10'E and is about 250 m above sea level. Soil (Typic Haplustep) of IARI research farm belongs to sub-tropical semi arid agro climatic zone (annual rainfall 651 mm) of the Upper Gangatic Plain. The soil (soil depth 0- 15 cm) of the experimental site was light in texture (sandy loam), alkaline in reaction with pH (1: 2.5): 8.4, organic carbon: 5.2 g kg^{-1} available nitrogen: 183 kg ha^{-1} available phosphorus: 22.4 kg ha^{-1} and available potassium: 188 kg ha^{-1}. The treatments details were as follows: T_1- FYM @ 20 t ha^{-1} in each crop (Organic), T_2 - Soil test based integrated fertilizer recommendations with 10 t ha^{-1} FYM (Integrated) (2.5 and 5.0 t ha^{-1} targeted grain yield of pearl millet and wheat, respectively), T_3- Soil test based chemical fertilizer recommendations (Chemical) (2.5 and 5.0 tha^{-1} targeted grain yield of pearl millet and wheat, respectively), T_4- Control (unfertilized) and were evaluated in randomized block design with four replications. Nutrients doses (kg ha^{-1}) were calculated from the fertilizer adjustment equations for targeting yield 2.5 and 5.0 t ha^{-1} of pearl millet and wheat crop respectively.

Calculated amount of nitrogen was applied as urea per treatments. Half dose of nitrogen was applied as a basal dose at sowing and the remaining half in two equal splits at tillering and heading of wheat crop and 15 days after sowing and knee high stage (45 days after sowing) in pearl millet. Phosphorus and potash was added as per treatment through DAP and murate of potash as basal dose at the time of sowing of pearl millet and wheat. The pearl millet crop was sown during the first week of July while sowing of wheat was done in the month of November during eight cropping sequence of pearl millet and wheat. The irrigation was given as per crops demand and hand weeding was done twice used for removing weeds from experimental field during each experiment. The yield (grain and straw of both crops) data was taken at the time of harvest. The soil samples were collected after harvest of each crop and analysed for different parameters. The pH and electrical conductivity (EC) of the soil extract was determined potentiometrically, using a pH electrode (Thermo Orion make) calibrated with a pH buffer of 7.0 and 9.2 pH and EC by conductivity electrode using a ORION ion analyzer (5 star series), Organic carbon determined by Walkley and Black method (Nelson and Sommers, 1996). Available nitrogen was analyzed by alkaline permanganate method (Subbaiah and Asija, 1956), available phosphorus by Olsen *et al*. (1954) and available potassium by ammonium acetate method (Hanway and Heidal, 1952). The analysis of available micronutrients in soil viz., Zn, Fe, Cu and Mn was carried out by DTPA extraction method (Lindsay and Norvell, 1978). Physical parameters of soil were determined by following standard procedures. The fresh soil samples collected at the maturity of wheat crop were immediately used for estimating biological properties. Soil microbial biomass carbon in soil was estimated by extraction method (Vance *et al.,* 1987). Dehydrogenase activity in soil was estimated by incubation with triphenyle tetrazolium chloride (TTC) and calcium carbonate method (Casida *et al.,* 1964). Statistical method (Gomez and Gomez,1984) was used for analysing the data.

Results and Discussion

The results revealed that grain and straw yield of pearl millet increased significantly with the STCR based integrated fertilizer recommendations with 10 t FYM ha^{-1} (T_2) as compared to other treatments. The increase in grain and straw yield of pearl millet in treatment T_1, T_2 and T_3 over control was 121 and 121%, 203 and197% and 159 and152 % respectively. The average highest grain yield (2.85 t ha^{-1}) of pearl millet crop was recorded with STCR based integrated fertilizer recommendations with 10 t FYM ha^{-1} (T_2), which achieved the targeted yield (2.5 t ha^{-1}). Further treatment T_2 was found to be superior over other treatments in respect of grain and straw yield of pearl millet crop. But treatment T_3 could not achieve the targeted yield in initial five years (up to 2008), thereafter the targeted yield was achieved in all the years. The average grain yield (2.43 t ha^{-1}) of pearl millet crop was recorded with chemical fertilizer (T_3) , which was 17 per cent higher over organic alone as @ 20 t FYM ha^{-1} application (T_1) but no significant difference was observed between both treatments T_1 and T_3 (Table 1). Similar trend was observed in straw yield of pearl millet. It was found on the basis of eight cropping sequence results that the integrated use of fertilizer with FYM increased the nutrient availability. This might be due to enhanced microbial activity, conversion of unavailable nutrients in to available forms and also due to improved physical, chemical and biological properties (Katkar *et al.,* 2011) that lead to increased productivity. Soil organic N is the largest source of plant available N to crops representing 50-80 % of total N- assimilated by crops (Eagle *et al.,* 2001)

The yield data presented in Table 2 showed significantly higher grain yield (5.32 t ha^{-1}) in STCR based integrated fertilizer recommendation treatment (T_2) that achieved targeted yield (5.0 t ha^{-1}) of wheat which was 14 % higher over STCR based fertilizer recommendations (Chemical fertilizer) T_3. Minimum average grain (1.80 t ha^{-1}) and straw (2.45 t ha^{-1}) yield of wheat was recorded in control (no fertilizer), which may be attributed to low available nutrient status in soil. Application of STCR based fertilizer recommendation (T_3) recorded average grain yield of 4.67 t ha^{-1}, could not achieve the targeted grain yield (5.0 t ha^{-1}) which was 7 % less. This decrease in wheat is in accordance with the hypothesis of STCR based fertilizer recommendations *i.e.* chemical fertilizer recommendations based on STCR gave ± 5 to 10 % variable yield as compared to targeted yield of the crop. Significant differences were observed among the treatments with respect to grain yield of wheat. Similar trend was observed in straw yield of wheat during the experimental period from 2003-04 to 2010-11. Highest average straw yield (7.17 t ha^{-1}) of wheat was recorded with STCR based integrated fertilizer recommendation (T_2) followed by STCR based fertilizer recommendations T_3 (6.13 t ha^{-1}), FYM alone @20 t ha^{-1} T_1 (4.69 t ha^{-1}) and control T_4 (2.45 t ha^{-1}). The improvement in grain and straw yield of wheat crop using STCR based integrated fertilizer recommendations with FYM (T_2) may be attributed to balance supply of nutrients for wheat crop from soil and improvement in physical, chemical and biological properties of soil which is in agreement with the findings of Singh *et al. (*1999), Katkar *et al.* (2011) and Yadav *et al.* (2005).

The application of FYM @ 10 t ha^{-1} improved the bulk density, water holding capacity (WHC) and infiltration rate of soil than STCR based integrated fertilizer recommendations. Non significant difference among different treatments in bulk density was observed after eight cropping sequence of pearl millet and wheat (Table-3) and ranged from 1.52 to 1.60 g cm^{-3}. Although significantly low values (1.52 and 1.54 g cm^{-3}) of bulk density were observed under FYM alone and integrated treatments respectively over control. Highest value (1.60 g cm^{-3}) of bulk density of soil was observed in control plots. Significant improvement in WHC and infiltration rate was noticed with FYM alone @ 20 t ha^{-1} (T_1) and STCR based integrated fertilizer recommendations application (T_2) compared to STCR based fertilizer recommendations (T_3) and control (T_4). Highest WHC (46.1%) and infiltration rate (3.5 cm hr^{-1}) of soil were observed in soil when FYM @20 t ha^{-1} was applied to the soil. These parameters *viz*. bulk density, water holding capacity and infiltration are the indicators of improvement in soil health due to addition of soil organic matter.

Table 1 : Grain and straw yield of pearl millet as influenced by STCR based fertilizers recommendation for targeted grain yield (2.5 t ha^{-1})

Treatments	Grain yield (t ha^{-1}) Years									Per cent increase over control
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Mean**	
T_1 : Organic	1.56	1.64	2.34	2.13	2.24	2.18	2.38	2.20	2.08	121
T_2 : Integrated	2.69	2.62	3.14	2.67	2.81	2.87	3.17	2.99	2.85	203
T_3 : Chemical	2.49	2.42	2.72	2.26	2.40	2.35	2.52	2.56	2.43	159
T_4 : Control	1.05	1.08	0.99	0.91	0.87	0.89	0.91	0.89	0.94	-
Mean	1..95	1.94	2.30	0.199	2.08	2.073	2.244	2.160		
S. Em ±	0.076	0.112	0.110	0.095	0.072	0.0554	0.0814	0.090		
C.D. at 5%	0.171	0.253	0.250	0.214	0.162	0.125	0.1840	0.203		
	Straw yield (t ha^{-1}) Years									**Per cent increase over control**
Treatments	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Mean**	
T_1 : Organic	3.56	3.80	5.44	5.03	5.26	5.30	5.66	5.25	4.91	121
T_2 : Integrated	6.17	6.04	7.60	6.22	6.36	6.83	7.21	6.83	6.59	197
T_3 : Chemical	5.94	5.43	5.79	5.27	5.79	5.49	5.66	5.71	5.60	152
T_4 : Control	2.35	2.37	2.30	2.21	2.05	2.19	2.11	2.08	2.22	-
Mean	4.507	4.409	5.28	4.682	4.863	4.95	5.159	4.968		
S. Em ±	0.1520	0.205	0.228	0.2300	0.175	0.128	0.141	0.176		
C.D. at 5%	0.3439	0.464	0.514	0.5204	0.397	0.290	0.318	0.3980		

Table 2 : Grain and straw yield of wheat as influenced by STCR based fertilizers recommendation for targeted grain yield (5.0 t ha^{-1})

Treatments	Wheat grain yield (t ha^{-1}) Years									Per cent increase over control
	2003-04	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**Mean**	
T_1 : Organic	3.42	3.62	3.79	3.69	3.74	3.69	3.56	3.75	**3.66**	103
T_2 : Integrated	5.38	5.37	5.24	5.40	5.48	5.33	5.11	5.23	**5.32**	196
T_3 : Chemical	5.08	4.87	4.81	4.63	4.43	4.48	4.35	4.73	**4.67**	159
T_4 : Control	1.81	1.80	1.75	1.82	1.80	1.67	1.67	2.08	**1.80**	-
Mean	**3.923**	**3.915**	**3.898**	**3.885**	**3.863**	**3.793**	**3.673**	**3.948**		
SEM	**0.152**	**0.107**	**0.127**	**0.091**	**0.061**	**0.0913**	**0.098**	**0.165**		
C.D. at 5%	**0.344**	**0.243**	**0.287**	**0.206**	**0.128**	**0.207**	**0.222**	**0.374**		
	Wheat straw yield (t ha^{-1})									
Treatments	**2003-04**	**2004-05**	**2005-06**	**2006-07**	**2007-08**	**2008-09**	**2009- 10**	**2010-11**	**Mean**	
T_1 : Organic	4.60	4.67	4.79	4.73	4.75	4.78	4.37	4.85	**46.9**	91
T_2 : Integrated	7.28	7.31	7.15	7.31	7.24	7.49	6.69	6.90	**71.7**	193
T_3 : Chemical	7.19	6.66	6.61	6.15	5.58	5.51	5.32	5.97	**61.3**	150
T_4 : Control	2.61	2.34	2.36	2.46	2.28	2.28	2.27	2.97	**24.5**	-
Mean	**5.42**	**5.245**	**5.228**	**5.163**	**4.963**	**5.02**	**4.663**	**5.173**		
SEM	**0.214**	**0.156**	**0.142**	**0.122**	**0.078**	**0.126**	**0.129**	**0.211**		
C.D. at 5%	**0.483**	**0.352**	**0.322**	**0.275**	**0.1768**	**0.285**	**0.291**	**0.477**		

Table 3 : Soil physico-chemical properties after eight pearl millet– wheat cropping sequence (2010-11)

Treatment	Bulk density (g cm^{-3})	WHC (%)	Infiltration rate (cm hr^{-1})	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (gkg^{-1})
T_1 : Organic	1.52	46.1	3.5	8.03	0.313	9.0
T_2 : Integrated	1.54	42.2	3.4	8.10	0.330	6.8
T_3 : Chemical	1.57	40.7	2.6	8.18	0.341	5.5
T_4 : Control	1.60	39.3	2.1	8.26	0.356	5.1
Mean	**1.56**	**42.1**	**2.9**	**8.14**	**0.333**	**6.5**
SEM	**0.02**	**0.56**	**0.03**	**-**	**0.02**	**0.261**
CD at 5%	**0.05**	**1.256**	**0.07**	**NS**	**0.05**	**0.589**

Where, WHC = Water holding capacity

Soil pH was not significantly influenced due to long term application of STCR based fertilizer recommendations application, FYM alone and control treatment (Table 3). It ranged from 8.03 to 8.26 in different treatments in the 0-15 cm soil depth. Continuous application of STCR based fertilizer recommendations and FYM alone had significant effect on electrical conductivity. Application of STCR based chemical fertilizer recommendations (T_3) however, slightly increased the electrical conductivity of soil over organic and integrated treatments (T_1 and T_2), which might be due to addition of salts through fertilizers to the soil. The highest electrical conductivity (0.356 dSm^{-1}) was observed in control (T_4) followed by STCR based fertilizer recommendations (0.341dSm^{-1}) (T_3) and STCR based integrated fertilizer recommendations with FYM treatment (0.330 dSm^{-1}) (T_2) while lowest electrical conductivity (0.313 dSm^{-1}) was observed in organic alone at application of 20 tonnes FYM ha^{-1} (T_1). Significant highest organic carbon 9.0 g kg^{-1} was recorded with FYM alone @ 20 tonnes ha^{-1} (T_1) followed by STCR based integrated fertilizer recommendations with 10 t FYM (6.8 g kg^{-1}) and lowest organic carbon (5.1 g kg^{-1}) in control. Significant difference was observed among different treatments in respect of soil organic carbon.

Long term application of FYM @ 20 tonnes ha^{-1} alone in each crop significantly enhanced available N 46.7 per cent and available K 56.3 per cent (Fig. 1) over their control while application of STCR based integrated fertilizer with FYM significantly increased the availability of nutrients N and K by 20.57 and 13.4 per cent, except available P compared with STCR based fertilizer recommendations (T_3) but the values of these available nutrients N and K were slightly low over organic alone (T_1). Lowest value of available nutrients N, P and K (174.3, 16.3 and 187.4 kg ha^{-1}) was recorded in control, respectively.

The DTPA-extractable micronutrients content in soil improved significantly with FYM @ 20 t ha^{-1} application in both the

Table 4 : DTPA-extractable micronutrients and biological properties after eight pearl millet– wheat cropping sequence (2010-11)

Treatment	DTPA-micronutrients (mg kg^{-1})				Biological properties	
	Zn	Fe	Cu	Mn	SMBC (µg g^{-1} dry soil)	DHA (µg TPF hr^{-1} g^{-1} soil)
T_1 : Organic	5.2	9.2	4.9	46.8	270.6	8.5
T_2 : Integrated	3.5	7.8	4.8	29.5	318.4	9.2
T_3 : Chemical	2.9	4.7	3.6	25.1	217.2	6.1
T_4 : Control	2.6	3.9	2.6	21.6	163.5	5.2
Mean	**3.2**	**4.3**	**3.9**	**30.8**	**242.4**	**7.2**
SEM	**0.087**	**0.769**	**0.415**	**1.247**	**3.21**	**0.21**
CD at 5%	**0.196**	**1.73**	**0.94**	**3.05**	**7.49**	**0.47**

Where, MBC= Soil microbial biomass carbon; DHA= Dehydrogenating activity

Table 5 : Economic analysis of different treatments for pearl millet –wheat cropping sequence (Average of eight cropping sequence)

Treatments	Pearl millet (t ha^{-1})		Wheat (t ha^{-1})		Grosse return from (grain+ straw)(Rs.ha^{-1})		Cost of input (Nutrients) (Rs.ha^{-1})		Net return (Rs ha^{-1})		Net return from sequence (Rs ha^{-1})	Extra return over control (Rs ha^{-1}yr^{-1})		Total return from system (Rs ha^{-1}yr^{-1})	Income Rs Re^{-1} spent on fertilizer (B:C ratio)
	Grain	Straw	Grain	Straw	Pearl-millet	Wheat	Pearl-millet	wheat	Pearl-millet	wheat		Pearl-millet	wheat		
T_1 : Organic	2.08	4.90	3.66	4.69	26085	48325	4000	4000	22085	44325	66410	10295	20200	30495	3.8
T_2 : Integrated	2.85	6.59	5.32	7.17	36535	71017	2947	3698	33588	67319	100907	21798	43194	64992	9.8
T_3 : Chemical	2.43	5.60	4.67	6.13	30270	62025	2148	3417	28122	58608	86730	16332	34483	50815	9.1
T_4 : Control	0.94	2.22	1.80	2.45	11790	24125	-	-	11790	24125	35915	-	-	-	-

Price taken for calculation: Rates: Rs 9000 t^{-1} for pearl millet grain; Rs 1500 t^{-1} for pearl millet straw; Rs 10000 t^{-1} for wheat grain; Rs 2500 t^{-1} for wheat straw; Nutrient cost: N -Rs 13 kg^{-1}; P_2O_5 -Rs 15 kg^{-1}; K_2O -Rs 10 kg^{-1}; FYM @ Rs 200 t^{-1}

crops over other treatments after eight cropping sequence of pearl millet –wheat (Table - 4). The highest DTPA-extractable Zn (5.2 mg kg^{-1}), Fe (9.2 mg kg^{-1}), Cu (4.9 mg kg^{-1}) and Mn (46.8 mg kg^{-1}) were found under FYM alone @ 20 t ha^{-1} application to both the crops. The STCR based integrated fertilizer recommendations significantly influenced DTPA-extractable micronutrients (Zn, Fe, Cu and Mn) in the soil (0-15 cm depth) over STCR based fertilizer recommendations and control. Moreover, the treatments which received FYM alone @ 20 tonnes ha^{-1} and STCR based integrated fertilizer recommendations showed more accumulation of available micronutrients in soil (0-15 cm depth) as compared to the chemical fertilizer recommendations and control. Meena *et al.* (2008) revealed that application of FYM @10 t ha^{-1} alone significantly enhanced the DTPA extractable Zn and Fe. Ismail *et al.,* (2004) also noted a significant build up of Zn, Cu, Mn and Fe in soil in the treatment receiving 50% recommended dose of fertilizer plus 5t FYM ha^{-1} under a long-term field experiment on vertisol.

Application of STCR based integrated fertilizer recommendations recorded significantly higher biological parameters *viz.* soil microbial biomass carbon (SMBC) was found to be 318.4 µg g^{-1} dry soil whereas dehydrogenase activity was 9.2 µg TPF hr^{-1} g^{-1} soil) which was 47.0 and 51.0 % higher as compared to STCR based fertilizer recommendations (Table 3) which might be due to the beneficial effect of STCR based integrated fertilizer recommendations on SMBC and dehydrogenase activity. Moreover this helped in increasing root biomass, growth and development of soil microorganisms. Application of FYM @20 tonnes ha^{-1} to each crop significantly increased SMBC and dehydrogenase activity over STCR based fertilizer recommendations and control which might be a steady source of organic carbon to enhance the microbial populations (Bhattacharyya *et al.,* 2008).The highest SMBC 318.4 µg g^{-1} dry soil in STCR based integrated fertilizer recommendations may be due to additional mineralizable and readily hydrolysable carbon from FYM and in conformity with Verma and Mathur, (2009) and Katkar *et al.,* (2011). The lowest SMBC value 163.5 µg g^{-1} dry soil was observed in control due to unfavourable environment arising out of depletion of nutrients due to continuous cropping without fertilization or organic manures. Application of STCR based integrated fertilizer recommendations recorded significantly higher dehydrogenase activity (9.2 µg TPF hr^{-1} g^{-1} soil) as compared to other treatments. The increase in dehydrogenase activity was 8.0 and 51.0% due to STCR based integrated fertilizer recommendations over FYM alone @ 20 tonnes ha^{-1} and STCR based fertilizer recommendations, respectively. The results are in conformity with the finding of Katkar *et al.* (2011) and

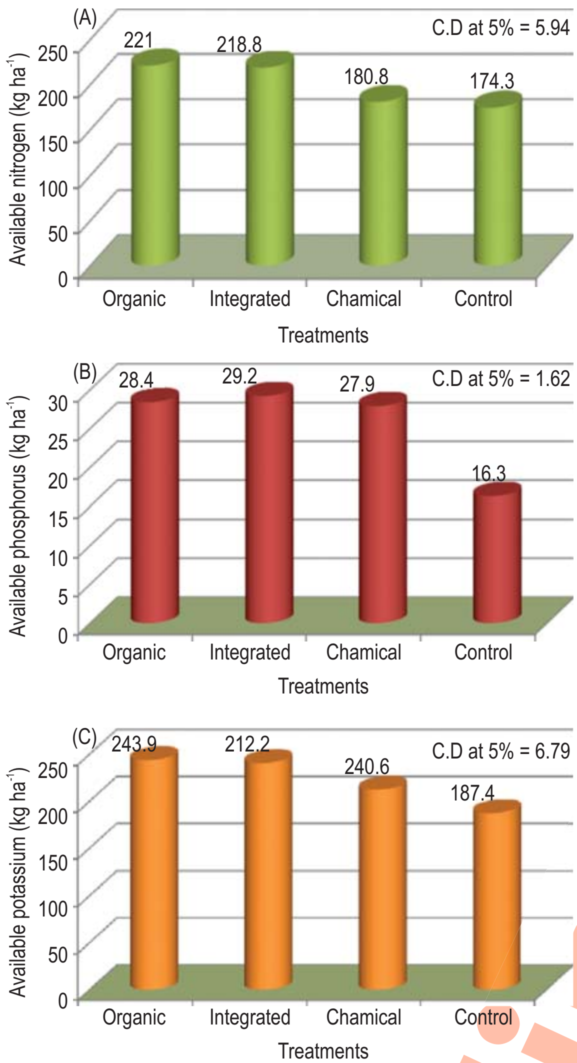

Fig. 1 : Change in fertility status after eight cropping sequence of pearl millet-wheat under long term STCR based fertilizers recommendation (2010-11)

observed significantly higher soil microbial biomass carbon and dehydrogenase activity due to the integrated use of fertilizer with FYM @ 10 t ha^{-1} as compared to FYM alone. Thereby suggesting balanced application of nutrients is necessary for improving dehydrogenase activity. Jain *et al.* (2003) also reported significant increase in DHA due to balanced nutrient application.

The economic feasibility of fertilizer treatment is an important deciding factor for adoption of recommendations by farmers of the concerned area for economic and viable crop production (Verma *et al.,* 2005). Therefore, the economic viability / efficiency of STCR based fertilizer recommendations (Integrated and chemical) and organic alone (FYM) was worked out in terms of gross returns, net return and B : C ratio of pearl millet- wheat cropping sequence. The maximum net return of Rs. 33588 $ha^{-1}yr^{-1}$ and Rs. 67319 ha^{-1} yr^{-1} were recorded for pearl millet and wheat crops, respectively with STCR based integrated fertilizer recommendations with FYM (T_2) and total net return of Rs.100907/ $ha^{-1}yr^{-1}$ of pearl millet-wheat cropping sequence in same treatment.

A perusal of data given in Table 5 further revealed that highest extra return of Rs. 21798 $ha^{-1}yr^{-1}$ and 43194 $ha^{-1}yr^{-1}$ from pearl millet and wheat respectively were recorded with STCR based integrated fertilizer recommendation with FYM (T_2) as well as total extra return from pearl millet-wheat cropping sequence was Rs. 64992 $ha^{-1}yr^{-1}$ over control. The STCR based fertilizer recommendation (chemical fertilizer) T_3 was found to be the second best treatment in providing the total extra return of Rs.50815 $ha^{-1}yr^{-1}$ from pearl millet – wheat cropping sequence. The higher income per rupee spent on fertilizers (B : C ratio) 9.8 was also observed with STCR based integrated fertilizer recommendations with FYM (T_2) for pearl millet-wheat cropping sequence as compared to other treatments.

It can be concluded that long term application of the integrated balanced nutrients (STCR based integrated nutrient recommendations with FYM @10 tonnes ha^{-1}) to both the crops can produce maximum grain and straw yield and achieve grain yield targets of both crops which would help in obtaining maximum total return (Rs. 64992 $ha^{-1}yr^{-1}$) Therefore, STCR based integrated fertilizer may be recommended as a economically viable recommendation and can be adopted by farmers in India.

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