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Impact of long term fertilization and manuring on sustainability yield index under rice-wheat cropping system in a vertisol of central India

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Abstract
A field experiment was conducted on the *Vertisol* at Research farm, Dept. of Soil Science and Agriculture Chemistry, College of Agriculture, Indira Gandhi Krishi Vishwavidhyalaya, Raipur, Chhattisgarh. The sustainable yield of wheat was higher in different treatment combinations over control as observed during assessment of sustainable yield index (SYI) at five year interval *i.e.* 2003-04, 2008-09, 20013-14 and 2018-19 as well as after continuous 20 years (1999-2019) of wheat yield. The sustainability in yield was increased with graded levels of balanced application of fertilizers from 50 to 150 % NPK. The balanced inorganic fertilization gave higher SYI than control. If graded levels of fertilizers with organic manure and biofertilizer (FYM, GM and BGA) were applied in *kharif* it appeared that application of higher levels in wheat had increased the SYI.

Keywords: SYI, long term fertilization, GM, FYM, BGA

Introduction
Long-term experiments provide one of the means to measure sustainable management systems in agriculture. They are records of the past and may serve as early warning systems for the future (Dawe *et al.,* 2000) [5]. In India, several long-term fertilizer experiments have indicated wide variability in crop productivity which has been attributed to continuous depletion of soil fertility (Swarup and Wanjari, 2000) [20].

Traditional method of agriculture rehearsed with intensive tillage operations, clean development (uncovered soil with no spread), single harvest developing or determined customary yield revolution, imbalanced manure use and little utilization of organics have brought about a great deal of issues in arable Indian grounds. Major problems in the arable lands of India are: deteriorating soil health (physical, chemical and biological); declining or stagnating yield trends of rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) (Ladha *et al.*, 2003) [10, 11] and farm income reduction (Aggarwal *et al.,* 2004) [1]; high surface water run-off and soil erosion (on average, 5-10 Mg/ha/year) (Pimentel, 2006) [14] and declining soil fertility. Conventional agricultural practices in the Indo-Gangetic Plains (IGP) has reduced soil fertility by reducing population of nutrient mineralising microbes, as these soils have low soil organic carbon (SOC) (Loke, 2012) [12]. In addition, declining soil aggregation attributed to intensive tillage, application of mineral fertilizers and pesticides in soils causes soil degradation.

It is very much archived that the focal issue in India is decrease of SOC in arable terrains (Naresh *et al.*, 2014) [13] and water shortage. The sustainability of the rice-wheat cropping system is in danger inferable from higher water necessity of the rice crop (Das *et al.*, 2014) [4], particularly in the IGP. The crops are growing for long time with different nutrient management practices as per the accessible input assets. Rice–wheat systems, as a result of several decades of consistent cropping and the differentiating edaphic prerequisites of the two grains, have indicated proof of soil supplement exhaustion and irregular characteristics, low nutrient use efficiency, a general decrease in soil organic matter, and deteriorating or declining yields (Dawe *et al.* 2000 and Ladha *et al.* 2003) [5, 10, 11]. There might be different variables behind yield stagnation of both the crops, for example, edaphic imperatives, invasion of insects and diseases, developing of nearby and vulnerable cultivars, unfriendly and fluctuating atmosphere conditions, traditional techniques for planting, rainfed cultivation practice of crop and low soil organic carbon combined with nitrogen status in soil.

Material and methods
Cropping System, Location, Climate and Soil
Raipur is situated at 21^0 4' North Latitude and 76^0 3' East Longitude with an altitude of 293 meter above mean sea level. The Research farm is located at National highway No.53 in eastern part of Raipur city and located between 20^0 4' North Latitude and 81^0 39' East Longitude with an altitude of 293 m above mean sea level. The area goes under sub-humid climate and the overall atmosphere of this locale is dry wet, sub humid and the district gets 1200-1400 mm precipitation every year, About 88 percent precipitation is gotten during stormy season (June to September) and 8 percent during winter season (October to February). May is the hottest and December is the coolest month of the year. The precipitation design has incredible varieties during blustery season from year to year. The temperature throughout the late spring months comes to as high as 47°C and drop to 7°C during December to January. The

experimental soil (*Vertisol*) is fine montmorillonitic hyperthermic chromustert locally called as *Kanhar* and is identified as Arang II series. It is usually deep, heavy clayey (50 %), dark brown to black in color and neutral to alkaline in reaction due to presence of lime concentrations.

Experimental details

The experiment was carried out in Randomized Block Design, replicated four times with ten permanent treatments *viz.* T_1-Control; T_2 - 50% of the recommended optimum NPK fertilizer dose (50:30:20::N:P_2O_5:K_2O,kg ha^{-1}); T_3 - 100% of the recommended optimum NPK fertilizer dose (100:60:40::N:P_2O_5:K_2O,kg ha^{-1}); T_4 -150% of the recommended optimum NPK fertilizer dose (150:90:60::N:P_2O_5:K_2O,kg ha^{-1}); T_5 - 100% of the recommended optimum NPK fertiliser + $ZnSO_4$ @25kg /ha in *kharif crops* only (100:60:40::N:P_2O_5:K_2O,kg ha^{-1} + $ZnSO_4$); T_6 - 100% N and P of recommended dose of fertilizer (100:60:0::N:P_2O_5:K_2O,kg ha^{-1}); T_7 - 100% N of recommended dose of fertilizer (100:0:0::N: P_2O_5:K_2O,kg ha^{-1}); T_8 - 100%NPK recommended fertilizer dose +FYM (5 t /ha in *kharif crop* only); T_9 -50% NPK recommended fertilizer dose +BGA (10kg/ha dry culture in *kharif* crop only); T_{10} - 50% NPK recommended fertilizer dose +GM (Sown in site, cut and mixed in soil in *kharif* season only)

Sustainability yield index

The sustainability yield index (SYI) was computed as suggested by Singh *et al.* (1990) and Sharma *et al.* (2002)

$$SYI = (\breve{y} - \sigma) / Y_m$$

Where,
$\breve{y}$ = Average yield of a treatment over the years
σ = Treatment standard deviation over the years
Y_m= Maximum yield in the treatment over the years

Results and discussion

The sustainability yield of wheat was higher in different treatment combinations over control as observed during assessment of sustainable yield index (SYI) of continuous 20 years (1999-2019) of wheat yield (Table 1). The sustainability in yield was increased with graded levels of balanced application of fertilizers from 50 to 150 % NPK. The balanced inorganic fertilization gave higher SYI than control. If graded levels of fertilizers with organic manure, biofertilizer (FYM, GM and BGA) were applied in *kharif* it appeared that application of higher levels in wheat had increased the sustainable yield index. Thus, significant residual effects were obtained due to application of different organic sources at various levels of major nutrients. Among the all treatments 150%NPK was found maximum sustainability followed by 100% NPK+FYM. Moreover all the organic sources were superior over Control. This means that application of FYM and green manuring provided minimum guaranteed potential yield in that particular environment.

Among the different treatments SYI of wheat was found in decreasing order of 100% NPK+FYM > 150% NPK > 100% NPK+ Zn > 100% NPK > 100%NP > 50% NPK+GM > 50% NPK + BGA > 50% NPK > 100%N and control. Similar results found by Prasad and Sinha (2000) and Gupta *et al.* (2006).

The perusal of data in table 1 on SYI of wheat revealed that it was higher under 100% NPK+FYM (0.85, 0.69, 0.53 and 0.56) comparable to 150% NPK (0.80, 0.71, 0.53 and 0.57), which were comparatively higher than 50% NPK + GM (0.55, 0.44, 0.35 and 0.38) and 50% NPK + BGA (0.52, 0.39, 0.32 and 0.35). The lowest SYI (0.32, 0.23, 0.19 and 0.20) was noticed in no manure, no fertilizer plot *i.e.* Control than all the other treatments in the years 2003-04, 2008-09, 2013-14 and 2018-19 respectively. Thus, the integrated use of organic and inorganic manures hold a great promise in providing greater stability and sustainability in crop production under the modern intensive farming by providing balanced nutrition and through correction of marginal deficiencies of secondary and micronutrient (Wanjari *et al*., 2004; Vats *et al*., 2003) [22, 21]. The data indicated that imbalanced fertilizer application, unfertilized and control caused decline in SYI due to decline in physical, chemical and biological properties of soil which could not sustain the yields of wheat for longer period. The SYI was considerably reduced at use of only inorganic fertilizers devoid of organics. Although the SYI values showed comparable figures at 100% dose of only inorganic fertilizers, the soil quality attributes showed fairly good improvement under conjunctive use of inorganic with organics. This indicates necessity of regular addition of organics in order to sustain crop productivity of cereal–cereal cropping system without declining the soil quality. The similar results were reported by Billore *et al.* (2006) [3], Katkar *et al.* (2010) [9] and Singh *et al.* (2014) [18]. The performance of nutrient management options for a period of 20 years was considered for this purpose. It appears that increase in the use of inorganic fertilizers increased the sustainability of system. The inclusion of organic sources further increased the sustainability in wheat yields. The use of green manures ensured highest sustainability of system. These results are similar with Kang *et al*. (2005) [8] who reported that rice-wheat system made sustainable by replacing 50% of the inorganic fertilizer N with FYM and green manure N (Gupta *et al.* 2006) [7]. The lack of sustainability of the inorganic fertilizer treated plots may be due to low microbial and crop indices and some other deficiencies. While the application of FYM that increased the organic matter content gave higher nutrient, microbial and crop indices than application of inorganic fertilizers thus making system more sustainable (Bhatnagar *et al.*, 2014) [2] and (Dutta *et al.*, 2015) [6]. Results of the experiment were found that the recommended dose of fertilizers along with organic manure would be a viable option for restoring soil organic carbon and nutrient turnover, thereby improving the availability of nutrients in soil, maintaining soil quality, and helping achieve sustainable productivity of wheat crops for the long run under irrigated moisture regimes. Continuous application of omitted PK or K from 100% NPK with Zn and/ or Zn from 100% NPK can markedly reduce the yield sustainability and soil quality (Ram *et al*., 2016) [16].

Among all organic sources of nutrients green manuring gave highest SYI than other options. This means that application of green manure provided minimum guaranteed yield of the potential yield in that particular environment.

Table 1: Long-term wheat yield and sustainable yield index at interval of five years

Years	**2003-04**		**2008-09**		**2013-14**		**2018-19**		
Treatments	Average yield (Q/ha)	SYI	Average yield (Q/ha)	SYI	Average yield (Q/ha)	SYI	Average yield (Q/ha)	SYI	Overall Mean SYI
Control	1248.47	0.32	1022.04	0.23	1062.69	0.19	1064.58	0.20	0.23
50% NPK	1641.96	0.50	1495.53	0.40	1695.19	0.32	1802.70	0.34	0.39
100% NPK	2423.70	0.71	2154.00	0.58	2424.00	0.45	2551.25	0.49	0.56
150% NPK	2691.16	0.80	2487.71	0.71	2808.14	0.53	2934.48	0.57	0.65
100% NPK+Zn	2359.44	0.74	2148.47	0.61	2424.26	0.46	2542.64	0.49	0.57
100% NP	2247.86	0.64	2106.93	0.58	2392.82	0.44	2510.49	0.48	0.54
100% N	1777.30	0.44	1469.25	0.33	1626.70	0.28	1660.97	0.30	0.34
100% NPK+FYM	2683.00	0.85	2460.30	0.69	2683.87	0.53	2825.03	0.56	0.66
50% NPK+BGA	1783.77	0.52	1557.58	0.39	1790.27	0.32	1896.95	0.35	0.39
50% NPK+GM	1806.18	0.55	1654.99	0.44	1895.88	0.35	2032.91	0.38	0.43

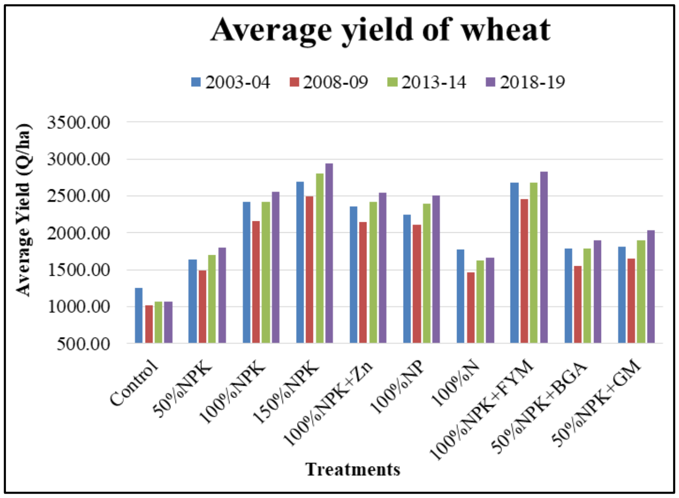

Fig 1: Long-term average wheat yield at five years interval since 1999 to 2019

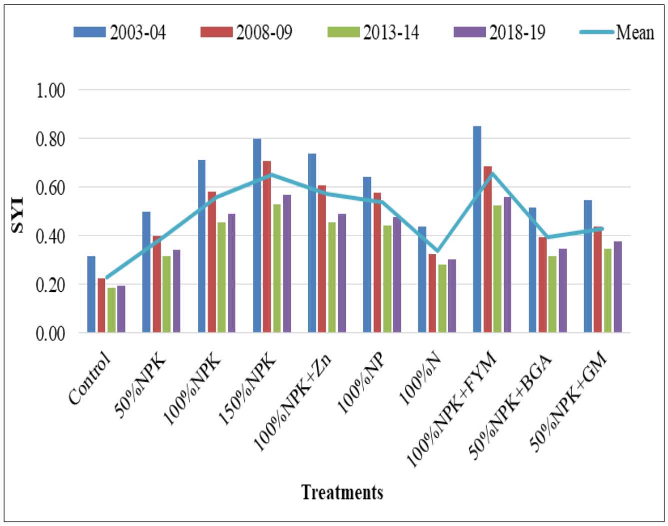

Fig 2: Effect of balanced and imbalanced fertilization on sustainable yield index

Conclusion

FYM and GM integrated with balanced fertilisation either optimal or sub optimal dose of NPK were the best option for long term sustainability or highest yields in this system followed by inorganic balanced fertilizer alone. Further, the continuous use of recommended dose of inorganic fertilizers we get sustainable yield of wheat over no fertilizer and manure (control).

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