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SS Bhosale
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

DG Jondhale
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

NH Khobragade
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

AV Dahiphale
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

SB Bhagat
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

TJ Bedse
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

NV Mhaskar
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

Corresponding Author:
DG Jondhale
Regional Agril. Research Station, Karjat, Dist Raigad, Maharashtra, India

Impact of integrated nutrient management on physical properties of inceptisols under rice - rice cropping system in North Konkan coastal zone of Maharashtra

SS Bhosale, DG Jondhale, NH Khobragade, AV Dahiphale, SB Bhagat, TJ Bedse and NV Mhaskar

Abstract
A study was conducted to assess the long term effects of inorganic fertilizers and organic manures on physical properties and crop productivity after 31th cycle of rice-rice cropping system as 62th crop during *kharif* 2017 and 63th crop during *Rabi*-hot weather 2017-18 at Model Agronomic Experimental Farm, Regional Agricultural Research Station, Karjat, Dist. Raigad, Maharashtra (18.92^0 N latitude, 73.33^0 E longitude and 52.0 m altitude) in *Typic Haplusteps*. The particle size distribution, textural class, bulk density, particle density and water holding capacity did not change significantly due to continuous application of inorganic fertilizers alone or organic manures plus inorganic fertilizers. Application of 50 per cent recommended NPK dose through fertilizers and 50 per cent N through FYM, paddy straw or glyricidia green leaf manuring (GGLM) during *kharif* season and 100 per cent recommended NPK dose through fertilizers during *rabi* season significantly reduced the bulk density and particle density while increased maximum water holding capacity of the soil. Long term application of Integrated Nutrient Management (INM) increase grain yield (25.07, 22.87 to 57.52, 57.87 q ha^{-1}) and straw yield (30.65, 28.14 to 68.36, 67.94 q ha^{-1}) in *Kharif* rice and *Rabi*-hot weather Rice respectively. Adoption of INM practices improved physical properties of soil along with yield under rice-rice cropping system in long run.

Keywords: INM, rice - rice cropping system, yield of rice, physical properties of soil

Introduction
It is well proven that long-term experiments generate extensive and valuable information which is used for studying the sustainability of intensive agriculture on long-term basis. Long term fertilizer experiments have been therefore undertaken both in India and abroad in order to know the changes in soil fertility as a result of continuous application of manures and fertilizers on long term basis. The famous broad black field experiment at Rothmsted in England initiated such manurial experiments in 1843. On the basis of same model, some long term manurial experiments were stared at different locations right from 1885 and being continued even today in India (Nambiar and Ghosh 1984 and Nambiar *et at.*, 1992) [22, 23]. Realizing the importance of sustainability of the production system in the years to come, the Indian Council of Agricultural Research sponsored the All India Coordinated Research Project on Long term Fertilizer Experiments (LTFE) during IV plan period September, 1970 at 11 different locations in India.

Some of the physical properties of soil are deteriorated with mere use of chemical fertilizers and its magnitude will differ under variable nitrite management. Application of chemical fertilizer in combination with organic manures increased percent water stable aggregates (>0.25mm), mean weight diameter, maximum water holding capacity, moisture retention, hydraulic conductivity and infiltration rate of soil (Kalane *et al.*, 1995) [18].

The data generated with long term fertilizer experiments in India indicated that continuous cropping without addition of nutrients resulted into depletion of these nutrients where as fertilization and manuring helped to restore the soil fertility depletions (Nambiar and Ghosh, 1984 and Nambiar *et al.*, 1992) [22, 23]. In North *Konkan* region Medium black soils are derived from deccan trap. The soils are highly argillaceous with fine texture and dark in colour. The soils are very tenacious to moisture and exceedingly sticky when wet on drying these from deep cracks. Continuous integrated use of organic manures and fertilizers would be quite promising in assessing the sustainability of a cropping system vis-a-vis monitoring the soil

Properties. The present investigation was, therefore, undertaken to study the "Influence of integrated nutrient management on physical properties of Inceptisols under rice – rice cropping system in North Konkan coastal zone of Maharashtra".

Materials and Methods

A long term field experiment was conducted under the aegis of All India Co-ordinated Research Project on IFS Long-term Fertilizer Experiments (AICRP-IFS) from 1986 to 2017 at MAE Farm, Regional Agricultural Research Station, Karjat, Dist. Raigad (18.92^0 N latitude, 73.33^0 E longitude and 52.0 m MSL) under North *Konkan* command area to study the effect of integrated nutrient management on yield and physical properties of soil over longer period in rice-rice cropping system. The experiment was laid out in a randomized block design with twelve treatments with different organic sources of nutrients (Treatment details are given in Table-1) with four replications. After harvest, the straw was weighed and treated as crop residue. The initial soil fertility levels were (pH - 6.40, EC - 0.13 dSm-1, organic carbon 6.8 g kg^{-1}, available Nitrogen 288.0 kg ha^{-1}, available phosphorus 12.3 kg ha^{-1}, available potash 211.4 kg ha^{-1}). The organic sources of nitrogen used were FYM (Farm Yard Manure), paddy straw and GGLM with nitrogen content of 0.5 per cent, 0.61 per cent and 2.74 per cent on dry weight basis respectively. Nutrient equivalent basis of organic sources to meet the required quantity of N were incorporated in the soil 15 days before transplanting of *kharif* paddy. Entire dose of P, K and 50 per cent of inorganic N were applied at the time of transplanting in the form of Single Super Phosphate, Muriate of Potash and Urea respectively. The remaining dose of nitrogenous fertilizer was top dressed in equal splits at tillering stage and flower initiation stage in the form of Urea. Rice variety *Palghr* -1 was grown as 62^{th} crop during reported period of 2017 during *Kharif* and *KJT*-3 as 63^{th} crop during reported period of 2017-2018 during *Rabi* season. The soil of experimental site was medium black *Typic Haplustepts*. The representative surface soil samples (0–22 cm) were collected from each treatment plot at harvest stage. The samples were air dried in shade, grinded in wooden mortar with pestle and sieved through 2 mm sieve. The soil separates such as sand, silt and clay in composite sample were estimated by Bouyoucos hydrometer method (Bouyoucos 1951) [9] and the textural class was determined with the help of textural triangle as outlined by (Chopra and Kanwar 1978). Bulk density was determined using clod coating method described by (Black 1965) [8]. Particle density was estimated by using Pycnometer as described by (Black 1965) [8]. Soil moisture was determined by using Keen-Raczkowski circular brass boxes as described by (Piper 1966). Various parameters were analyzed statistically following the analysis of variance procedure as described by Gomez and Gomez (1984) [15].

Results and Discussion

Crop yields

During both the seasons (*Kharif* and *Rabi*-hot weather) application of organic and inorganic source of nutrients significantly increased grain yields of rice compared to untreated control. Application of 50 per cent RDF along with 50 per cent RDN through FYM (T_6) to 62^{th} *Kharif* rice crop (*Palghr* -1) and 63^{th} *Rabi*-hot weather crop (*KJT*-3) (Table-3) produced maximum and significantly higher grain (57.52, 57.87 q ha^{-1}) and (68.36, 67.94 q ha^{-1}) straw yield as compared to rest of the treatments except the treatments T_{10} (application of 50 per cent RDF through fertilizers and 50 per cent RDN substitution through GGLM) and T_5 where 100 per cent RDF (NPK) was applied through fertilizers. During both season minimum grain yield (25.07, 22.87 q ha^{-1}) and straw yield (30.65, 28.14 q ha^{-1}) were recorded respectively under control. The increase in yield was associated with application of inorganic fertilizers in combination with organic manures may be due to its greater availability and uptake of macro and micro-nutrients and active participation in carbon assimilation, photosynthesis, starch formation, translocation of protein and sugar, entry of water into plants root and development etc. It also enhances the process of tissue differentiation *i.e.*, from somatic to reproductive phase leading to higher grain and straw yield. The results are also in conformity with findings of Prasad (1994) [27], Kher (1993) [19] and (Singh *et al.*, 2000) [33].

Bulk Density

A critical look on data presented in Table 4 and Table 5 revealed that the treatment receiving No fertilizers, no organic manures (T_1) recorded the highest value of bulk density (1.32, 1.33 g cm^{-3}) whereas the lowest value of bulk density was seen in the treatment receiving application of 50% recommended NPK dose through fertilizers and 50% N through FYM (T_6) (1.28, 1.29) during both the season respectively. The bulk density of soil varied from 1.28 to 1.32 g cm^{-3} in *Kharif* season and 1.29 to 1.33 g cm^{-3} in *Rabi* season. Bandyopadhyay *et al.*, (2010) [3] and Nandapure *et al.*, (2011) [24] found similar result of BD and it was reduced significantly with the 100% NPK+ FYM treatment over all other treatments at surface soil. The extent of reduction of BD was more when organic manures were applied along with inorganic fertilizers. Marginal reduction in BD in NPK treated plots could be ascribed to the increased root biomass production that might have increased organic matter content of the soil (Bharadwaj and Omanwar, 1992) [5]. Continuous application of chemical fertilizers along with organics for 17 cropping cycles caused highest decrease in the BD of soil may be due to addition of higher organic carbon that resulted in more pore space and good soil aggregation (Mishra and Sharma 1997, Babhulkar *et al.* 2000, Sheeba and Kumaraswamy 2001, Selvi *et al.* 2005, Gupta *et al.* 2006 and Chaudary and Thakur, 2007) [21, 1, 32, 30, 16, 10]. Prasad and Singh (1980) [26] also reported increase in bulk density of soil where only chemical fertilizers were applied (1.45 g cm^{-3}) as compared to control (1.36 g cm^{-3}) on acidic red loam soil with wheat-maize cropping system after elapsed period of 20 years. The physical properties of soil change very slowly and showed marginal variations during long period. However, in the present study, it was observed that continuous use of organics recorded considerable decrease in BD. The significant reduction in BD from control to Integrated Nutrient Management treatment using FYM, GGLM, rice straw indicating the importance of organics in the improvement of tilth of soil. The reduction in bulk density may be attributed to better aggregation, increased porosity and improvement in soil structure caused due to increased in soil organic matter under the treatment of integrated use of chemical fertilizers and organic manures. Selvi *et al*. (2005) [30] conducted long term fertilizer experiment at Coimbatore for 26 years and observed that soil porosity, hydraulic conductivity and water holding capacity were significantly higher in organo-inorganic combination (FYM + 100% NPK)

than in unmanured control excluding bulk density. The similar findings were reported by Sharma, M.P. and Bali, S. V. (2000) [31] and Gayatri Verma *et al*. (2010) [14]. The physical properties of soil changes very slowly and shows gradual variations during short period. However, in the present study, it was observed that continuous use of organics in combination with inorganics for period of 31 years recorded significant change in bulk density. The significant reduction in bulk density was recorded due to integrated nutrient management indicating importance of organics in improvement of physical properties of soil. The bulk density showed declining trend due to conjoint use of chemical fertilizers and FYM than that of only chemical fertilizers.

Particle density (g cm^{-3})

Particle density (PD) was determined in soil sample of different treatments in *Typic Haplustepts* under rice-rice cropping system in the year 2017-18 and is presented in Table 4 and Table 5. The data depicted in Table 4 and Table 5 revealed that PD of different treatments ranged from 2.47 to 2.50 g cm^{-3} in *Kharif* season and 2.48 to 2.51 g cm^{-3} in *Rabi* season. During both season lowest PD was recorded in T_6 *i.e.* (50 per cent recommended NPK dose through fertilizers and 50 per cent N through FYM) which was identical to T_{10} *i.e.* (75 per cent recommended NPK dose through fertilizers and 25 per cent N through GGLM). The higher value of particle density was observed in control and imbalanced application of fertilizer where as balanced dose fertilizer and INM treatments show lower value. The lowest value of Particle density (PD) was recorded in combined application of inorganic and organic nutrient practices (using FYM, GGLM and Rice straw). Particle density of soil is an inherent capacity of soil and it doesn't change the addition of organic and inorganic fertilization. Similar results were presented by Walia and Rao (1996) [34], Ram *et al*., (2010) [29].

Maximum water holding capacity (%)

The data regarding maximum water holding capacity (MWHC) during *Kharif* and *Rabi* season of soil as influenced by long term fertility treatment are presented in Table 4 and Table 5. The data presented in Table 4 and Table 5 revealed that water holding capacity (WHC) of different treatments ranged from (56.97 to 62.79%) in *Kharif* and (55.55 to 61.95%) in *Rabi* season and the treatment differences were statistically significant. Maximum and significantly higher water holding capacity was ascribed in treatment T_6 (integration of 50 per cent recommended NPK dose through fertilizers along with 50 per cent N through FYM) which was at par with T_{10} (50 per cent recommended NPK dose and 50 per cent N through GGLM) over rest of the treatment combinations in both the season over their initial values. The lowest value of WHC recorded in control and imbalanced dose fertilizer. While, the highest values were recorded in balanced application of integrated nutrient management practices (FYM, GGLM and Rice straw). The MWHC of soil increased significantly with application of 50 per cent recommended NPK dose through fertilizers and 50 per cent N through FYM during *kharif* season and 100 per cent recommended NPK dose through fertilizers during *rabi* season (T_6) over control. This could be attributed to the addition of organic materials and also due to root growth and more plant residues after harvest. These results are in conformity with the findings of Bellaki and Badanur (1997) [4]. The organic matter added in turn helps in increasing the WHC of the crop. Similar findings were obtained by Bhatanagar *et al*., (1992) [7], Badanur *et al.* (1990) [2] and Masto *et al.* (2007) [20] who reported that the physical condition of soil, improved water retention significantly by the application of FYM with NPK for 31 years on *Inceptisol* in long-term fertilizer experiments at IARI, New Delhi. Hudson (1994) [17] reported that soils high in organic matter have greater available WHC than soils of similar texture with less organic matter. Gattani *et al*. (1976) [13] also observed significant increase in MWHC of alluvial soil (pH: 8.0) with application of FYM alone (27.8%) as compared to control (25.8%) and also treatment receiving only chemical fertilizers (23.4 to 25.7%) with the exception of phosphatic fertilizers where the MWHC of soil was increased from 25.8 to 26.5 per cent as compared to control. Rabindra *et al*. (1985) [28] also observed increase in MWHC with the application of only FYM from 30.1 to 40.2 per cent as compared to control and also over only chemical fertilizer treatments (33.1 to 36.2%) in slightly acidic soil under sugarcane as a test crop after period of 11 years.

Particle size distribution (%)

It is evident from the data presented in Table 6 that long term integrated nutrient management treatment did not significantly change per cent content of sand, silt and clay in medium black soil during both the season. Therefore, the texture of soil *i.e.* clayey did not change among the various treatment inspite of elapsed period of 31 years. The content of sand, silt and clay ranged from 18.15 to 19.68, 20.34 to 23.73 and 56.59 to 61.24 per cent respectively during *Kharif* and the corresponding range values for *Rabi* season were 18.32 to 19.85, 20.23 to 23.62 and 56.53 to 61.18 per cent respectively. A critical look on data further revealed that all the treatment combinations did not show significant effect on per cent sand content of the soil. In general, it is seen that the majority of soil samples were found to be clayey in texture (Table 6). Further, it is also seen that clay content of all the soils showed decreases in sand and silt fractions in soil. Thus, in general, it could be stated that particle size distribution and textural class did not change due to continuous application of either organic manures, chemical fertilizers or manures plus chemical fertilizers after a lapsed period of 31 years. Gaikwad and Khupse (1976) [12] reported that similar results on black soil *Rabi* jowar and cotton cropping system under rainfed condition after 38 years of lapsed period.

Table 1: Treatments Details

Tr. No	*Kharif* Rice	Tr. No.	Rabi Rice
T_1	No fertilizers, no organic manures	T_1	No fertilizers, no organic manures
T_2	50% recommended NPK dose through fertilizers	T_2	50% recommended NPK dose through fertilizers.
T_3	50% recommended NPK dose through fertilizers.	T_3	100% recommended NPK dose through fertilizers.
T_4	75% recommended NPK dose through fertilizers	T_4	75% recommended NPK dose through fertilizers
T_5	100% recommended NPK dose through fertilizers	T_5	100% recommended NPK dose through fertilizers
T_6	50% recommended NPK dose through fertilizers + 50% N through FYM	T_6	100% recommended NPK dose through fertilizers
T_7	75% recommended NPK dose through fertilizers + 25% NPK through FYM	T_7	75% recommended NPK dose through fertilizers
T_8	50% recommended NPK dose through fertilizers + 50% N through rice straw	T_8	100% recommended NPK dose through fertilizers
T_9	75% recommended NPK dose through fertilizers + 25% N through rice	T_9	75% recommended NPK dose through fertilizers
T_{10}	50% recommended NPK dose +50% N through *Glyricidia* green leaf manure (GGLM)	T_{10}	100% recommended NPK dose through fertilizers
T_{11}	75% recommended NPK dose through fertilizers + 25% N through GGLM	T_{11}	75% recommended NPK dose through fertilizers
T_{12}	Farmer's practice (45:45:45 NPK kg ha^{-1})	T_{12}	Farmer's practice (90:45:45 NPK kg ha^{-1})

Table 2: Nutrient composition of various organic manures and inorganic fertilizers in the study

Sr. No.	Name of fertilizer	Composition (%)		
		N	P_2O_5	K_2O
1.	Urea	46.0	-	-
2.	Single super phosphate	-	16.0	-
3.	Muriate of potash	-	-	60.0
4.	FYM	0.50	0.25	0.50
5.	*Glyricidia* green *leaf* manures (GGLM)	2.74	0.50	1.15
6	Rice straw	0.61	0.16	1.14

Table 3: Long term effect of application of manures and fertilizers on grain yield and straw yield of medium black soil after thirty one years

Treatments	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})	
	Kharif 2017	*Rabi* 2017-18	*Kharif* 2017	*Rabi* 2017-18
T_1= UTC:0 -0	25.07	22.87	30.65	28.14
T_2= RDF:50 - 50	43.25	40.59	51.49	48.01
T_3= RDF:50 - 100	51.80	53.66	60.77	62.29
T_4= RDF:75 - 75	51.89	50.39	60.78	56.32
T_5= RDF:100 - 100	56.79	56.98	67.60	65.19
T_6= RDF:50+FYM:50N –100	57.52	57.87	68.36	67.94
T_7= RDF:75+FYM:25N – 75	54.54	50.70	63.88	56.65
T_8= RDF:50+RS:50N – 100	52.36	55.31	61.46	63.40
T_9= RDF:75+RS:25N – 75	52.06	49.75	61.30	56.15
T_{10}= RDF:50+GGLM:50N -100	56.93	57.38	67.68	66.29
T_{11}= RDF:75+GGLM:25N- 75	53.61	49.76	63.69	56.59
T_{12}=FP 45+45+45 - 90+45+45	41.33	38.56	49.65	45.44
S.E. (m) ±	0.78	1.39	1.13	1.50
C.D. at 5%	2.45	4.38	3.57	4.74

Table 4: Long term effect of application of manures and fertilizers on Bulk density, Particle density and Maximum water holding capacity of medium black soil after thirty one years during *Kharif* season

Treatments	*Kharif* 2017		
	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Maximum water holding capacity (%)
T_1= UTC:0 -0	1.32	2.50	56.97
T_2= RDF:50 - 50	1.31	2.49	57.66
T_3= RDF:50 - 100	1.31	2.48	57.93
T_4= RDF:75 - 75	1.31	2.48	58.07
T_5= RDF:100 - 100	1.29	2.49	60.15
T_6= RDF:50+FYM:50N –100	1.28	2.47	62.79
T_7= RDF:75+FYM:25N – 75	1.30	2.49	59.77
T_8= RDF:50+RS:50N – 100	1.29	2.48	58.35
T_9= RDF:75+RS:25N – 75	1.30	2.48	58.21
T_{10}= RDF:50+GGLM:50N -100	1.29	2.47	61.06
T_{11}= RDF:75+GGLM:25N- 75	1.30	2.49	59.39
T_{12}=FP 45+45+45 - 90+45+45	1.31	2.50	57.52
S.E. (m) ±	1.30	2.48	58.99
C.D. at 5%	0.02	0.03	0.61

Table 5: Long term effect of application of manures and fertilizers on Bulk density, Particle density and Maximum water holding capacity of medium black soil after thirty one years during *Rabi* season

Treatments	*Rabi* 2017-18		
	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Maximum water holding capacity (%)
T_1= UTC:0 -0	1.33	2.51	55.55
T_2= RDF:50 - 50	1.32	2.50	56.83
T_3= RDF:50 - 100	1.32	2.49	58.58
T_4= RDF:75 - 75	1.30	2.49	57.24
T_5= RDF:100 - 100	1.30	2.49	59.32
T_6= RDF:50+FYM:50N –100	1.29	2.48	61.95
T_7= RDF:75+FYM:25N – 75	1.31	2.50	57.55
T_8= RDF:50+RS:50N – 100	1.30	2.49	58.96
T_9= RDF:75+RS:25N – 75	1.31	2.50	57.10
T_{10}= RDF:50+GGLM:50N -100	1.30	2.48	60.26
T_{11}= RDF:75+GGLM:25N- 75	1.31	2.50	57.41
T_{12}=FP 45+45+45 - 90+45+45	1.31	2.50	56.71
S.E. (m) ±	1.31	2.49	58.12
C.D. at 5%	0.02	0.03	0.65

Table 6: Long term effect of application of manures and fertilizers on Particle Density and Textural Class of medium black soil after thirty one years

Treatment details	*Kharif* 2017			Textural Class	*Rabi* 2017-18			Textural Class
	Sand (%)	Silt (%)	Clay (%)		Sand (%)	Silt (%)	Clay (%)	
T_1= UTC:0 -0	18.15	20.61	61.24	Clay	18.32	20.50	61.18	Clay
T_2= RDF:50 - 50	18.80	20.68	60.52	Clay	18.97	20.57	60.46	Clay
T_3= RDF:50 - 100	18.82	21.39	59.79	Clay	19.62	21.52	58.86	Clay
T_4= RDF:75 - 75	19.59	20.62	59.79	Clay	18.99	21.28	59.73	Clay
T_5= RDF:100 - 100	19.3	22.64	58.06	Clay	19.48	22.53	57.99	Clay
T_6= RDF:50+FYM:50N –100	19.68	23.73	56.59	Clay	19.85	23.62	56.53	Clay
T_7= RDF:75+FYM:25N – 75	18.30	22.97	58.73	Clay	18.18	22.74	59.08	Clay
T_8= RDF:50+RS:50N – 100	18.01	22.85	59.14	Clay	18.47	22.86	58.67	Clay
T_9= RDF:75+RS:25N – 75	18.88	21.72	59.40	Clay	19.77	20.51	59.72	Clay
T_{10}=RDF:50+GGLM:50N -100	19.41	23.28	57.31	Clay	19.59	23.17	57.24	Clay
T_{11}= RDF:75+GGLM:25N- 75	19.44	21.63	58.93	Clay	19.05	21.38	59.57	Clay
T_{12}=FP 45+45+45 - 90+45+45	18.96	20.34	60.70	Clay	19.13	20.23	60.64	Clay
Mean	18.95	21.87	59.18	Clay	19.11	21.74	59.14	Clay
S.E. ±	1.16	1.10	0.82		1.17	1.09	2.36	
C.D. at 5%	N.S.	N.S.	N.S.		N.S.	N.S.	N.S.	

Conclusion

Application of nutrient through combined sources of organic and inorganic fertilizer did not show significant effect on mechanical composition, bulk density, and particle density of the soil after harvest of the rice. The application of RDN through FYM was found to produce statistically significant effect on maximum water holding capacity over rest of the treatment combination. Use of chemical fertilizers in conjunction with organic manures (FYM, GGLM and rice straw) had positive and superior influence in improving MWHC of soil as compared to control. Inclusion of organic nutrients from varied sources *viz.*, FYM, GGLM and paddy straw can be seen as a supplemental alternative to enhance the fertility basket which will ensure higher productivity and profitability to farmers.

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