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EFFECT OF INM ON NUTRIENTS UPTAKE AND YIELD OF MAIZE-WHEAT CROPPING SEQUENCE AND CHANGES IN NUTRIENT AVAILABILITY IN TYPIC HAPLUSTEPTS

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ABSTRACT
Integrated nutrient management (INM) is an important tool to sustain of nutrients availability plants and improve soil fertility without any risk to environment. Field experiments were carried out during 2014-15 and 2015-16 under the ongoing AICRP on LTFE with Maize-Wheat cropping in Typic Haplustepts that initiated during *kharif* 1997 at the Instructional Farm of Rajasthan College of Agriculture, Udaipur. The experiment consisted of 12 treatment combinations *viz.*, T_1- Control, T_2- 100%N, T_3- 100%NP, T_4- 100%NPK, T_5- 100%NPK + Zn,

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INTRODUCTION

Improving fertiliser usage efficiency by matching soil nutrient availability with crop demand is the goal of Integrated fertiliser Management (INM), which is the concept of combined application of organic, inorganic, and biological nutrient sources (Graham et al., 2017). Divers' actions vary from those of integrated chemical fertiliser and organic input farmers, which is emphasised by modern agriculture technology (Tamilselvi et al., 2017). According to Nath et al. (2017), the soil microbiome and enzymes may be improved by varying amounts and types of crop waste, farmyard manure, and biological fertilisers. The fast depletion of soil micronutrients in India has been accelerated by intense cropping with nutrient exhausting high yielding cultivars and the use of high analysis fertiliser to enhance food grain production (Singh, 2009). Soil biological characteristics must be monitored for the long-term effects of inorganic fertilisers and integrated nutrient management strategies (inorganic fertilisers + organic amendments). Parkinson (2013) and Zhang et al. (2012) found that integrated nutrient management (INM) significantly increases crop yields while reducing nutrient losses to the environment and managing the nutrient supply. This leads to high resource-use efficiency, cost reductions, and improved nutrient availability. Therefore, INM is a viable model for agriculture to guarantee the safety of food and enhance environmental conditions globally, particularly in nations whose economies are undergoing fast development.

According to Rao and Reddy (2005), crop productivity was stabilised at low to medium cropping intensities by continuous FYM dressing, while under modern intensive farming, crop productiOn was stabilised by integrated organic and chemical fertilisers. The recent decline in soil health due to the global energy crisis and the skyrocketing prices of chemical fertilisers have prompted calls to augment these expensive inputs with more cost-effective organic and biological fertilisers (Kumar and Dhar, 2010). These biofertilizers are great for farmers since they are cheap, lightweight, and kind to the environment. Soils in Rajasthan are generally poor in organic matter content and nutrient supply; however, by introducing appropriate biological fertiliser strains to these soils, production can be enhanced via an increase in microbial population, which in turn increases nitrogen fixation and phosphorus mobilisation. Meeting local food demands and maintaining food security are both supported by the maize-wheat farming system. Double cropping with maize (Zea mays L.) and wheat (Triticum aestivum L.) is the most common and well-known method under irrigated conditions in the northwest region of India. Historically, maize and wheat have been grown on oceans. According to Jat et al. (2013), the major crop rotation in India is still maize, which accounts for 1.8 million hectares and contributes around 3.0% of the country's food supply. In light of these considerations, the current research set out to determine how INM influences nitrogen absorption, yield, and variations in nutrient availability in Typic Haplustept soil, as well as the maize-wheat cropping sequence. analysis of variance (ANOVA) method to RBD. Whenever the 'F' test showed significance, the crucial difference (CD) at a 5% level was assumed (Panse and Sukhatme, 1985). The absorption of these nutrients by grain and straw was estimated by taking samples of each and analysing them.

MATERIALS AND METHODS

In 2014–15 and 2015–16, the experiment took place at the Instructional Farm of the Rajasthan College of Agriculture in Udaipur. Located at 24°35′ N latitude and 74°42′ E longitude, the location is 579.5 m above mean sea level in the southeastern region of Rajasthan. The area is located in Rajasthan's agroclimatic zone IVa, which is the subhumid southern plain and the Arawali Hills. The region has a tropical climate, which means that summers are warm and associated with high humidity, especially from July to September. The majority of the 570-620 mm of precipitation that falls in the region each year falls in the southern and western monsoons from July through September. Summertime highs may reach up to 44°C and minimum temperature during December and January falls as low as 1°C. Initial status of available nutrients in LTFE field during 1997 was clay loam in texture having pH 7.45, EC 0.47 dSm^{-1}, Organic carbon 0.67%, available nitrogen 360.0 kg ha^{-1}, available phosphorus 22.67 kg ha^{-1} and available potassium 671.15 kg ha^{-1} and DTPA extract Zn, Fe, Cu and Mn values are 3.76, 2.52, 3.12, and 17.4 ppm, respectively. The experiment consisted of 12 treatment combinations *viz.*, T_1- Control, T_2- 100%N, T_3- 100%NP, T_4- 100%NPK, T_5- 100%NPK + Zn, T_6- 100%NPK + S, T_7- 100%NPK + Zn + S, T_8- 100% NPK + *Azotobacter*, T_9- 100% NPK + FYM 10 t ha^{-1}, T_{10} - FYM 10 t ha^{-1} + 100%NPK (-NPK of FYM), T_{11} - 150%NPK and T_{12} - FYM @ 20 t ha^{-1} with four replications in a randomized block design. Maize variety PEHM-2 and wheat var. Raj-4037 was sown. The sources used for applying N, P and K were urea, DAP (adjusted for its N content) and muriate of potash, respectively. Gypsum and zinc sulphate ($ZnSO_4.7H_2O$) were used to supply S and Zn in that order. Fertiliser made from Azotobacter sp. and farm yard manure, or FYM, were the two organic nutrient sources used. Each plot had soil samples taken before sowing and after harvest from two distinct depths (0–15 and 15–30 cm, respectively). For the purpose of analysing these samples, the following methods were used: the alkaline permanganate method (Subbiah and Asija, 1956), Olsen's method (Olsen et al., 1954), the ammonium acetate extractiOn method (Richards, 1954), and the atOmic absorption spectrophotometer (Lindsay and NOrvell, 1978) for the determination of available micronutrients (Zn, Cu, Fe, and Mn).

Spectrophotometric estimates of nitrogen content were made in wheat (grain and straw) and maize (grain and stalk) using Nessler's reagent (Snell and Snell, 1959), whereas estimates of phosphorus content were made using Vanadom.The olybdate phosphoric acid yellow colour technique was developed by Jackson in 1973. The flame photometer method was also developed by Jackson in 1973. Linday and Norvell (1978) estimated the micronutrients (Fe, Mn, Cu, Zn) using AAS.

The experimental data were analyzed using analysis of

RESULTS AND DISCUSSION

Yield

Grain and stover yield of maize -wheat crop as influenced by application of INM (organic manures + fertilizer application) presented in (Table 1). A perusal of data indicated that the grain and stover yield of maize -wheat increased significantly with the incorporation of 100% NPK + FYM 10 t ha^{-1} treatment (T_9) over control. The highest maize grain yield 4033 and 4053 kg ha^{-1} and stover yield 5290 and 5320 kg ha^{-1} was recorded under 100% NPK + FYM 10 t ha^{-1} treatment (T_9) during 2014-15 and 2015-16, respectively (Table 1). Similarly, the highest wheat grain yield 4939 and 5107 kg ha^{-1} and straw yield 7217 and 7270 kg ha^{-1} was recorded under 100% NPK + FYM 10 t ha^{-1} treatment (T_9) during both years on pooled basis (Table 1). This might be due to fact that application of INM as integrative chemical fertilizers and organic manures application was, however, found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production by synergistic effect of FYM on improving efficiency of optimum dose of NPK and corrective deficiency of Zn. The results of the present study are in line with those reported by Behera and Singh (2010), Paradkar *et al*. (2010), Singh *et al.* (2014) and Kumar *et al.* (2014). Similarly results also showed that application of 100 % NPK with *Azotobacter* seed treatment increased the yield of maize and wheat over control. These are in confirmation with findings of Jaipaul *et al.* (2008).

Nutrient contents in maize and wheat

Application of INM brought about significant improvement in nitrogen, phosphorus and potassium content in grain and stover of maize and wheat during both the years of research (two tables). Out of all the treatments, applying 100% NPK with FYM 10 t ha-1 resulted in the greatest improvement in the nitrogen, phosphorous, and potassium content in the grain and straw of wheat and maize. The amount of fertilisers applied and the concentration of nutrients close to the root zone determine how much of these nutrients plants absorb (Singh and Sarkar, 1985). The usage of organics in conjunction with chemical fertilisers may have increased the soil's nutrient supply after mineralization or decomposition, which explains why the concentrations of nitrogen, phosphorus, and potassium have risen. But still, T7, which included applying 25 kg of ZnSO4 together with sulphur and 100% NPK, yielded the maximum zinc content in the grain and straw of wheat and maize, whereas T5, which involved applying 100% NPK and zinc, reached the lowest. All treatments with FYM as compared to control showed a substantial improvement in Zn content. In both years, the application of 100% NPK + FYM 10 t ha-1 resulted in the maximum iron, copper, and manganese content in the grain and straw of wheat and maize. One possible explanation for FYM's favourable influence on micronutrient concentrations is the direct provision of these catiOns on

Table 1: Effect of INM on yield of maize and wheat under maize-wheat cropping system

Treatments	Maize yield (kg ha^{-1})						Wheat yield (kg ha^{-1})					
	Grain			Stover			Grain			Straw		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
T_1-Control	1327	1325	1326	2190	2200	2195	1552	1609	1326	2190	2200	2195
T_2-100% N	2169	2112	2141	3500	3470	3485	2915	3012	2141	3500	3470	3485
T_3-100% NP	2806	2829	2817	4090	4140	4115	3591	3620	2817	4090	4140	4115
T_4-100% NPK	3220	3266	3243	4610	4660	4635	4270	4320	3243	4610	4660	4635
T_5-100% NPK+Zn	3382	3390	3386	4790	4820	4805	4495	4520	3386	4790	4820	4805
T_6-100%NPK+S	3297	3313	3305	4730	4790	4760	4393	4430	3305	4730	4790	4760
T_7-100% NPK+Zn + S	3516	3530	3523	4870	4920	4895	4592	4610	3523	4870	4920	4895
T_8-100% NPK+*Azotobacter*	3402	3400	3401	4910	4880	4895	4401	4450	3401	4910	4880	4895
T-100%NPK+FYM 10 t ha^{-1}	4033	4053	4043	5290	5320	5305	4939	5107	4043	5290	5320	5305
T-FYM 10 t ha^{-1}+100% NPK (-NPK of FYM)	3490	3466	3478	4650	4635	4642	4585	4620	3478	4650	4635	4642
T_{11}-150% NPK	3605	3630	3618	5180	5250	5215	4640	4680	3618	5180	5250	5215
T-FYM 20 t ha^{-1}	2435	2414	2425	3160	3100	3130	3077	3105	2425	3160	3100	3130
SEm±	91	93	65	151	159	110	119	124	65	151	159	110
CD (P = 0.05)	263	269	184	436	458	310	341	358	184	436	458	310

Table 2: Effect of INM on pooled nutrient contents in grain and stover of maize under maize-wheat cropping system

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (ppm)		Iron (ppm)		Copper (ppm)		Manganese (ppm)	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
T1	1.195	0.365	0.206	0.089	0.400	1.098	18.53	13.40	98	311	8.72	5.19	59.42	48.15
T2	1.365	0.397	0.238	0.113	0.425	1.335	18.87	13.67	99	313	8.99	5.35	59.67	48.81
T3	1.490	0.407	0.273	0.130	0.426	1.344	19.02	13.93	99	314	9.52	5.65	60.24	48.93
T4	1.474	0.473	0.283	0.131	0.442	1.373	19.45	14.62	102	318	10.43	7.31	60.36	49.38
T5	1.496	0.488	0.268	0.131	0.454	1.353	24.28	18.07	102	318	10.81	7.78	61.34	49.35
T6	1.530	0.498	0.251	0.126	0.465	1.348	20.54	14.49	102	318	9.64	7.61	61.66	49.77
T7	1.504	0.492	0.275	0.132	0.472	1.355	24.79	17.80	102	319	10.31	7.37	61.77	49.88
T8	1.597	0.492	0.280	0.144	0.476	1.370	19.43	13.72	101	309	11.46	7.26	60.27	48.70
T9	1.590	0.505	0.290	0.140	0.459	1.369	23.14	16.36	110	319	12.74	8.70	66.91	52.94
T10	1.552	0.488	0.277	0.140	0.467	1.417	22.40	16.15	109	317	12.54	8.48	66.37	52.01
T11	1.623	0.525	0.335	0.153	0.503	1.494	21.23	15.81	103	311	11.22	7.98	62.30	50.52
T12	1.390	0.420	0.267	0.128	0.440	1.265	19.67	13.14	101	309	11.76	7.55	61.94	50.39
SEm±	0.015	0.005	0.003	0.001	0.005	0.015	0.224	0.145	0.81	4.42	0.079	0.077	0.539	0.651
CD (P = 0.05)	0.042	0.014	0.008	0.004	0.014	0.041	0.632	0.410	2.30	NS	0.224	0.218	1.523	1.838

Table 3: Effect of INM on pooled nutrient contents in grain and straw of wheat under maize-wheat cropping system

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (ppm)		Iron (ppm)		Copper (ppm)		Manganese (ppm)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T1	1.135	0.300	0.205	0.084	0.360	0.913	16.33	11.45	96	305	7.02	4.94	56.92	46.31
T2	1.270	0.312	0.232	0.086	0.376	0.936	16.45	11.66	96	306	7.17	5.05	57.28	47.43
T3	1.335	0.320	0.258	0.095	0.389	0.950	16.70	11.78	97	307	7.68	5.29	57.77	47.75
T4	1.381	0.372	0.273	0.101	0.396	0.973	17.62	12.57	99	308	8.93	6.62	58.59	48.46
T5	1.396	0.381	0.269	0.103	0.405	0.948	19.34	14.62	98	307	8.81	6.83	58.80	48.58
T6	1.350	0.376	0.264	0.096	0.407	0.941	17.68	12.77	97	307	8.27	6.55	57.68	48.59
T7	1.409	0.388	0.272	0.101	0.406	0.952	19.48	14.89	98	307	8.87	6.75	58.81	48.80
T8	1.397	0.382	0.260	0.102	0.411	0.971	17.92	12.60	98	308	9.25	6.48	58.79	48.01
T9	1.430	0.393	0.280	0.117	0.418	1.010	19.17	14.05	108	313	10.77	7.89	63.74	51.64
T10	1.389	0.386	0.272	0.114	0.414	0.988	18.86	13.75	107	312	10.51	7.61	63.41	51.35
T11	1.453	0.410	0.290	0.133	0.439	1.040	18.45	13.65	101	309	9.73	7.15	60.42	50.32
T12	1.340	0.339	0.267	0.120	0.407	0.995	17.45	11.92	102	308	10.58	7.35	61.43	50.70
SEm±	0.014	0.004	0.003	0.001	0.004	0.008	0.191	0.124	0.800	3.94	0.067	0.071	0.521	0.578
CD (P = 0.05)	0.039	0.011	0.011	0.002	0.012	0.022	0.539	0.350	2.259	NS	0.189	0.199	1.470	1.633

decomposition of FYM, which leads to mineralization and the solubilization of organic acids, and indirectly to FYM's beneficial impact on the soil environment. The results are consistent with those of Khan et al. (2006) and Roshani et al. (2005).

Nutrient uptake by maize and wheat

Results showing the impact of integrated nutrient management interventions on crop-specific nutrient absorption in grain and straw are shown in Table 4. Attained the maximum soluble nitrogen absorption by maize, which was 91.09 kg ha-1.

Table 4: Effect of INM on nutrients uptake (total) by maize under maize-wheat cropping system

Treatments	Nitrogen ($kg\ ha^{-1}$)		Phosphorus ($kg\ ha^{-1}$)		Potassium ($kg\ ha^{-1}$)		Zinc ($g\ ha^{-1}$)		Iron ($g\ ha^{-1}$)		Copper ($g\ ha^{-1}$)		Manganese ($g\ ha^{-1}$)	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
T1	23.86	24.97	4.69	5.20	29.40	27.07	540	527	8133	8693	229	172	1844	1985
T2	43.09	51.20	9.00	10.62	55.63	52.02	880	997	13008	16240	379	324	2978	3768
T3	58.75	65.43	13.04	14.43	67.34	65.29	1109	1238	15721	20075	501	420	3711	4658
T4	69.70	83.09	15.22	18.17	77.96	79.22	1308	1561	18036	23989	677	599	4245	5616
T5	74.08	88.16	15.35	18.95	80.40	81.01	1691	1840	18743	24814	740	618	4448	5865
T6	74.26	84.05	14.28	17.90	79.53	79.18	1369	1612	18508	24299	681	589	4407	5707
T7	77.09	91.31	16.14	19.43	82.96	83.49	1744	1903	19190	25444	724	647	4618	6027
T8	78.47	88.33	16.59	18.57	83.33	85.34	1333	1665	18544	25672	746	641	4435	5924
T9	91.09	100.23	19.13	22.25	91.16	93.15	1804	1987	21395	28159	977	813	5515	6944
T10	76.78	91.20	16.16	20.59	82.01	88.98	1531	1838	18547	26956	829	770	4725	6545
T11	86.05	94.05	20.07	22.03	96.15	90.67	1591	1735	19959	24604	822	685	4889	6040
T12	46.87	57.01	10.48	13.76	50.30	58.17	888	1086	12104	17305	521	505	3078	4221
SEm±	1.38	1.980	0.313	0.403	1.796	1.847	26	36	381	523	11	45	74	110
CD (P = 0.05)	3.91	5.590	0.885	1.137	5.071	5.216	73	101	1076	1476	32	128	208	310

Table 5: Effect of INM on available nutrients (pooled) after harvest of wheat under maize-wheat cropping system at different depth (cm) in soil

Treatments	Nitrogen ($kg\ ha^{-1}$)		Phosphorus ($kg\ ha^{-1}$)		Potassium ($kg\ ha^{-1}$)		Zinc (ppm)		Iron (ppm)		Copper (ppm)		Manganese (ppm)	
Depth (cm) ⇒	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
T1	253	257	15.42	15.29	496	485	2.04	2.00	2.59	2.55	1.65	1.60	9.02	8.95
T2	266	269	15.61	15.38	479	471	2.22	2.11	2.67	2.60	1.63	1.61	9.75	9.66
T3	277	280	22.65	22.18	487	477	2.52	2.45	3.07	3.02	1.95	1.90	9.50	9.39
T4	347	348	23.41	23.14	549	552	2.44	2.38	2.95	2.90	1.93	1.94	9.70	9.58
T5	342	343	23.63	23.40	581	579	3.69	3.62	3.11	3.05	2.14	2.08	9.81	9.69
T6	342	344	24.38	24.19	554	549	2.46	2.41	3.30	3.26	2.25	2.14	10.34	10.18
T7	338	340	26.94	26.53	563	567	3.67	3.52	3.47	3.39	2.21	2.11	11.16	10.97
T8	375	376	26.74	26.30	558	552	2.54	2.51	3.26	3.17	1.75	1.70	11.09	10.92
T9	466	471	30.19	29.79	585	583	3.50	3.47	3.72	3.64	2.57	2.51	13.00	12.84
T10	402	404	25.79	25.36	595	591	3.45	3.40	3.55	3.45	2.49	2.44	12.85	12.73
T11	368	372	29.79	29.62	598	589	2.47	2.42	2.88	2.79	1.82	1.77	9.49	9.40
T12	304	308	24.45	24.19	581	578	2.75	2.70	2.95	2.91	2.35	2.29	13.58	13.42
SEm±	3.20	3.43	0.224	0.240	5.57	4.94	0.029	0.030	0.032	0.032	0.022	0.022	0.112	0.114
CD(P=0.05)	9.05	9.69	0.631	0.677	15.72	13.94	0.083	0.085	0.089	0.090	0.061	0.062	0.317	0.323

Table 6: Effect of different treatments on nutrient balance in soil during both maize-wheat cropping system (2014-15 and 2015-16)

Treatments	Nutrient addition through manure and fertilizers ($kg\ ha^{-1}$)			Total nutrient uptake by maize-wheat sequence($kg\ ha^{-1}$)			Nutrient balance after completion of two years($kg\ ha^{-1}$)		
	N	P	K	N	P	K	N	P	K
T_1- Control	0	0	0	97.25	19.78	112.95	-97.65	-19.78	-112.95
T_2- 100% N	480	0	0	188.57	39.26	215.29	291.43	-39.26	-215.29
T_3- 100 NP	480	240	0	248.36	54.96	265.25	231.64	185.04	-265.25
T_4- 100% NPK	480	240	120	305.58	66.8	314.35	174.42	173.2	-194.35
T_5- 100% NPK + Zn	480	240	120	324.49	68.61	322.81	155.51	171.39	-202.81
T_6- 100% NPK+ S	480	240	120	316.63	64.38	317.41	163.37	175.62	-197.41
T_7- 100% NPK+ Zn + S	480	240	120	336.79	71.13	332.91	143.21	168.87	-212.91
T_8- 100% NPK +*Azotobacter*	480	240	120	333.61	70.32	337.34	146.39	169.68	-217.34
T - 100% NPK + FYM 10 t ha^{-1}	576	268	210	382.64	82.76	368.63	193.36	185.24	-158.63
T - FYM 10 t ha^{-1} +100% NPK (-NPK of FYM)	480	240	120	335.97	73.48	341.98	144.03	166.52	-221.98
T_{11}- 150% NPK	720	360	180	360.20	84.18	373.64	359.80	275.82	-193.64
T_{12} - FYM 20 t ha^{-1}	192	72	180	207.75	48.5	216.96	-15.75	23.5	-36.96

as compared to other treatments, the application of 100% NPK + FYM was much superior. However, a 150% NPK application, followed by a 100% NPK + FYM treatment, resulted in the maximum P and K absorption in maize, at 20.07 and 96.15 kg ha-1, respectively. The peak performance Under 100% NPK + FYM application, followed by 150% NPK application, wheat uptaked 100.23 kg ha-1 of N, 22.25 kg ha-1 of P, and 93.15 kg ha-1 of K, respectively. At 1804, 21395, 977, and 5515 ppm, respectively, zinc, copper, iron, and manganese are the micronutrients that maize absorbs the most.

by wheat i.e. 1987, 28159, 813 and 6944 ppm respectively, was recorded under integrated use of 10 t ha^{-1} FYM and RDF i.e. 100% NPK. Zinc uptake under this treatment was at par with application of 100% NPK + Zn + S (T_7) and 100% NPK + Zn (T_5). These facts due to applications of FYM not only solubilize the unavailable nutrients but also contains significant quantity of nitrogen, phosphorus, potassium, and other micronutrients. Therefore, the use of FYM has led to a considerable improvement in nutrient absorption, with a marked decrease in the cost over a longer period of time. Maintaining increased productivity and ensuring steady crop yields for sustainable agricultural production may be achieved via the combined use of organic manure and chemical fertiliser. These findings corroborate those of Behera and Singh (2010), Das et al. (2010), and Sharma et al. (2013).

Nutrient availability

After the maize-wheat sequence was finished, the combined application of several plant nutrients greatly improved their status in the soil at the time of wheat harvest (Table 5). The application of 100% NPK+ FYM at a rate of 10 t ha-1 resulted in the maximum available nitrogen at both depths. Subsurface soils (15-30 cm) had the highest nitrogen availability values, which increased throughout INM treatments. Comparing the available nitrogen content in soil following wheat crop harvest during the experimental year to starting values, results revealed that higher nitrogen application improved the content. In comparison to other INM treatments, the application of 100% NPK+ FYM 10 t ha-1 and 150% NPK improved the availability of phosphorus at both depths. When comparing surface soils (0-15 cm) to subsurface soils (15-30 cm), the availability of phosphorus was found to be greater in the former. There was a significant increase in the available P status of the soil when phosphorus was applied at STR and 150% NPK, in comparison to when no phosphorus was applied. It is likely that the mobilisation of native soil phosphorus led to an increase in P availability, since the concentration of phosphorus in the soil rose with an increase in the amount of phosphorus. It is possible to enhance the availability of organic phosphorus via mineralization and acidification of the soil solution microenvironment when several nutrients are applied at vitamin P. Applying 150% NPK increased the amount of potassium in surface oils to its maximum. The highest potassium availability, however, was seen in subsurface soils when applied at a rate of 100% NPK+ FYM 10 t ha-1. The higher potassium levels in the 150% NPK treatment are a result of the higher potassium application rates in this treatment. FYM is known to be a direct source of potassium and also helps to reduce leaching loss by retaining K+ ions on exchange sites and releasing potassium through organic matter interactions with clay. The results are consistent with those of other studies conducted in the country and overseas, including those by Totawat et al. (2001), Verma et al. (2005), Singh et al. (2013), and Meena et al. (2017). When compared to their starting points, the amounts of available zinc at both depths dropped. At 0–15 cm and 15–30 cm, respectively, the maximum DTPA–Zn concentrations were 3.69 and 3.62 ppm, when applied with 100% NPK + Zn. In a balanced proportion or at the recommended amount, Goyal (2002) found that adding zinc to NPK increased the efficiency of both substances, which led to a continued synergistic interaction. Feiziasl and Valizadeh (2005) and Dwivedi et al. (2007) both revealed findings that are consistent with the current research (2007). We achieved the greatest DTPA-Fe levels using the application of 100% NPK + Zn + S application. The availability also increased at both depths as compared to initial values. The highest available copper was recorded with application of 100% NPK+ FYM 10 t ha^{-1} at both depths. Application of FYM@ 20 t ha^{-1} recorded the highest available manganese in surface and subsurface soils. The increase in available nutrient status of soil might be due to microbial as well as chemical activities. An improvement in available nutrient status of the soil with the incorporation of chemical fertilizer could be attributed to conserved soil nitrogen and increased availability of other nutrients as being its constituent as well as mineralize from the native source in soil. The results of present investigation are in line with the finding of Gill (2003).

Nutrient balance

There was a reduction in available nitrogen and an improvement or maintenance of phosphorus with INM treatments compared to the original values (Table 6). Regardless of the therapy, the available potassium contents dropped. Fertilisers, whether used alone or in combination with organic manure, significantly increased the amount of accessible nitrogen and phosphorus. When compared to nitrogen and potassium, phosphorus is immobile in soil. The lack of phosphorus in the fertilisation schedule is the obvious reason of a negative P balance, whereas the addition of phosphorus in excess of the crop's intake results in a positive P balance. Dwivedi et al. (2007) found results that are consistent with these findings. Indicative of commendable mining of available K, the trend of available K reducing from its original state was seen due to continuous farming. According to Swarup (2000), Thakur et al. (2011), and Kumar et al. (2013), this is in agreement.

CONCLUSIONS

The current study's findings suggest that wheat cv. Raj-4037 and maize cv. PEHM-2, which are classified as hyper-thermic Typic haplustepts of Udaipur, need 10 t ha-1 of FYM in conjunction with 100 % NPK (120 kg N, 60 kg P_2O_5, and 30 kg K_2O ha-1).

based on soil test for higher productivity and to maintain soil health.

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