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Influence of integrated nutrient management on yield and uptake of nutrients by maize and soil fertility under irrigated conditions in Vertisol

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Abstract: A field experiment was conducted in Vertisol of Malaprabha command of Karnataka to study the effect of integrated nutrient management in maize. Five years pooled data revealed that significantly higher grain yield (77.60 q ha^{-1}), fodder yield (122.69 q ha^{-1}) and NPK uptake was observed in recommended dose of fertilizer (RDF) plus biofertilizer (*Azospirillum* + PSB @ 350 g ha^{-1}) with one row of sunhemp between two rows of maize (sunhemp incorporated at 45 days after sowing) as compared to rest of the treatments. However, fifth year results indicated that application of 75% RDF plus maize stalk incorporation with cellulolytic culture plus biofertilizer (*Azospirillum* + PSB @ 350 g ha^{-1}) and one row of sunhemp between two rows of maize (sunhemp incorporated at 40 days after sowing) was on par with 100 % RDF in respect of yield and NPK uptake. Among irrigation levels, significantly higher grain yield (70.26 q ha^{-1}) was recorded at 0.8 IW/CPE moisture regime. Pooled data on uptake of N, P and K by maize was non-significant with respect to irrigation levels. Significant increase in organic carbon (0.46 to 0.67 %) content was recorded due to INM treatments. Recommended dose of fertilizer plus one row of sunhemp between two rows of maize plus biofertilizer recorded highest available nitrogen (208.9 kg ha^{-1}), phosphorus (31.0 kg ha^{-1}) and potassium (815.1 kg ha^{-1}) in soil after five years.

Key words: Maize, Nutrient uptake, Soil fertility, Sunhemp, Vertisol

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops used as food, fodder and raw materials for several industrial usage. Introduction of high yielding varieties/ hybrids of maize and adoption of improved production technologies enhanced the productivity of maize that resulted in more turn-over of the nutrients from the soil. Increasing prices of chemical fertilizers and their deleterious effects on environment have led to the use of organic sources of nutrients with chemical fertilizers. Sustainable yield levels could be achieved only by applying appropriate combination of green manures or organic manures and chemical fertilizers (Chandrashekar *et al*., 2000). Long term field experiments have made clear the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003). Continuous use of inorganics without organics reported deficiencies of nutrients in Vertisols of Malaprabha command, which might result in the decline in the productivity and poor soil health. In order to maintain soil health and productivity, a field experiment was initiated during 2007-08 to study the effect of integrated nutrient management on soil health and productivity of maize under varied moisture regime in Vertisol.

Material and methods

A field experiment was conducted at the Water Management Research Centre, Belvatagi, University of Agricultural Sciences, Dharwad (Karnataka) on Typic Calciustert for five years from 2007-08 to 2011-12. The initial status of the soil sample of the experimental field (0-20 cm depth) was with pH- 8.2, EC- 0.2 dSm^{-1}, Organic carbon- 0.52 %, available nitrogen- 186 kg ha^{-1}, available P_2O_5 - 32 kg ha^{-1}, available K_2O-791 kg ha^{-1}, field capacity- 32.0 per cent, and permanent wilting point- 21.0 per cent.

The experiment involved three levels of moisture regimes (0.8, 0.6 and 0.4 IW/CPE) and five levels of nutrient management systems [F_1 = Recommended dose of fertilizer (RDF), F_2 = RDF + Biofertilizers (BF) (*Azospirillum* + PSB), F_3= RDF + BF + Green manure (GM) (sunhemp), F_4 = 75% RDF + maize stalk incorporation with cellulolytic culture + BF + GM, F_5 = 50% RDF + maize stalk incorporation with cellulolytic culture+ BF + GM]. Farm yard manure was applied to all the treatments @ 10 t ha^{-1}. During *kharif*, maize was the test crop under irrigation and received 150 kg N, 75 kg P_2O_5 and 37.5 kg K_2O ha^{-1}. All other practices recommended by the Package of Practices of University of Agricultural Sciences, Dharwad was followed. Soil and plant analysis were carried out using standard procedures as outlined by Jackson (1973) and Black *et al.* (1965).

Results and discussion

The pooled five years research results showed that, significantly higher grain yield (77.60 q ha^{-1}) and fodder yield (122.69 q ha^{-1}) was observed in RDF plus biofertilizer (*Azospirillum* + PSB @ 350 g/ha) with one row of sunhemp between two rows of maize as compared to rest of the treatments (Table 1). Similar results of increase in maize grain and stover yield was found by Balai *et al.* (2011) with 100% NPK fertilizer plus FYM and Azotobacter as compared with 100% NPK only. This might be attributed to the addition of higher amount of nutrients through organic and green manures in conjunction with inorganic fertilizer, which resulted in higher maize grain and fodder yield. Fifth year results indicated that the grain yield in 100% RDF (63.78 q ha^{-1}) was on par with 75% RDF plus biofertilizer (*Azospirillum* + PSB @ 350 g/ha) with one row of sunhemp between two rows of maize and maize stalk incorporation with cellulolytic culture (61.43 q ha^{-1}). This clearly indicates that,

Table 1. Effect of INM practices and irrigation levels on maize grain and fodder yield (2007 - 2011 and Pooled)

	Grain yield (q ha^{-1})						Fodder yield (q ha^{-1})					
Treatments	2007	2008	2009	2010	2011	Pooled	2007	2008	2009	2010	2011	Pooled
Main-Irrigation levels												
I_1 - (0.8 IW/CPE)	68.6	74.27	79.33	55.93	73.17	70.26	115.9	121.5	109.2	78.6	124.22	109.05.
I_2 - (0.6 IW/CPE)	70.40	70.85	73.37	53.29	64.51	66.49	106.6	100.5	101.3	77.4	137.97	104.75
I_3 - (0.4 IW/CPE)	68.70	59.07	70.26	53.59	59.50	62.33	125.7	100.9	99.9	76.7	123.00	108.22
S.Em.±	4.59	1.640	0.824	1.825	1.926	1.615	7.11	5.66	0.987	0.377	2.375	4.099
C.D. (0.05)	NS	6.441	3.236	NS	7.562	5.269	NS	NS	3.877	NS	9.327	13.369
Sub- INM Treatments												
F_1- RDF	69.4	70.27	77.75	54.81	63.78	67.20	114.1	106.3	103.8	76.96	125.00	106.85
F_2- RDF+BF (*Azospirillum* + PSB)	76.6	75.03	78.44	56.36	68.95	71.07	126.7	116.2	109.3	80.44	138.38	115.69
F_3- RDF+BF+GM (one row of sunhemp between two rows of maize)	85.8	82.47	85.07	59.24	75.38	77.60	141.3	130.0	114.1	82.22	143.78	122.69
F_4- 75% RDF + Maize stalk incorporation with cellulolytic culture+BF+GM	63.7	64.41	73.37	51.86	61.43	62.96	101.9	95.3	100.0	75.62	123.71	99.79
F_5- 50% RDF + Maize stalk incorporation with cellulolytic culture+ BF+GM	50.6	49.13	56.95	49.08	59.09	52.98	96.3	90.3	91.3	75.22	111.11	91.66
S.Em.±	1.87	2.359	1.392	1.326	1.171	1.240	2.61	5.66	1.074	0.738	7.700	1.824
C.D. (0.05)	5.47	6.884	4.063	3.869	3.417	3.525	7.6	NS	3.135	2.153	22.476	5.185
Interaction (Irrigation levels x INM treatments)												
S.Em.±	5.43	4.085	2.411	2.747	2.645	2.510	8.17	2.45	1.860	1.203	12.163	4.978
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	7.14	NS	NS	NS	NS

RDF-Recommended dose of fertilizer, BF- Biofertilizers, GM- Green manure, NS- Non-significant

INM practices can save 25 per cent chemical fertilizer and increase the availability and uptake of nutrients.

Five years pooled data indicated that moisture regimes significantly influenced higher grain yield (Table1) and not significant with water use efficiency (WUE) of maize (Table 2). A higher grain yield (70.26 q ha^{-1}) was realized at I_1 moisture regime (IW/CPE = 0.8). However water use efficiency was significantly influenced with respect to integrated nutrient levels. The significantly higher water use efficiency of 21.12 kg ha^{-1}. mm was found in RDF plus biofertilizer (*Azospirillum*+PSB @ 350 g ha^{-1}) with one row of sunhemp between two rows of maize compared with rest of the treatments (Table 2). Similar results in maize by INM treatments were obtained by Karke *et al.* (2005) and Ramesh *et al.* (2008).

Five years pooled results indicated that, the uptake of NPK in maize was significantly superior (Table 3) at F_3 (N-218.4 kg ha^{-1}, P- 40.51 kg ha^{-1}and K- 239.8 kg ha^{-1}) followed by F_2 (N- 190.9 kg ha^{-1}, P- 36.36 kg ha^{-1}and K- 220.0 kg ha^{-1}),

Table 2. Effect of INM practices and irrigation levels on water use efficiency (kg ha^{-1}.mm) by maize (2007 -2011 and Pooled)

Treatments	2007	2008	2009	2010	2011	Pooled
Main-Irrigation levels						
I_1 - (0.8 IW/CPE)	13.00	20.75	19.13	14.60	19.28	17.36
I_2 - (0.6 IW/CPE)	15.09	23.78	18.50	14.43	20.18	18.38
I_3 - (0.4 IW/CPE)	14.72	22.35	18.11	14.52	22.92	18.52
S.Em.±	0.927	0.570	0.417	0.485	0.562	0.523
C.D. (0.05)	NS	2.240	NS	NS	2.206	NS
Sub- INM Treatments						
F_1- RDF	15.79	23.05	19.45	14.67	20.26	18.64
F_2- RDF + BF (*Azospirillum* + PSB)	14.29	24.58	19.63	15.08	21.80	19.08
F_3- RDF + BF + GM (one row of sunhemp between two rows of maize)	17.70	26.95	21.27	15.85	23.81	21.12
F_4- 75% RDF + Maize stalk incorporation with cellulolytic culture +BF+ GM	13.15	20.96	18.36	13.88	19.43	17.15
F_5- 50% RDF + Maize stalk incorporation with cellulolytic culture+ BF+GM	10.42	15.91	14.25	13.14	18.66	14.45
S.Em.±	0.392	0.747	0.350	0.357	0.359	0.371
C.D. (0.05)	1.145	2.179	1.022	1.042	1.049	1.054
Interaction (Irrigation levels x INM treatments)						
S.Em.±	1.108	1.290	0.684	0.736	0.791	0.777
C.D. (0.05)	NS	NS	NS	NS	NS	NS

RDF-Recommended dose of fertilizer, BF- Biofertilizers, GM- Green manure, NS- Non-significant

Table 3. Effect of INM treatments and irrigation levels on uptake of nitrogen, phosphorus and potassium by maize (2007 - 2011 and Pooled)

Treatments	Nitrogen (kg ha^{-1})						phosphorus (kg ha^{-1})						Potassium (kg ha^{-1})					
	2007	2008	2009	2010	2011	Pooled	2007	2008	2009	2010	2011	Pooled	2007	2008	2009	2010	2011	Pooled
Main-Irrigation levels																		
I_1 - (0.8 IW/CPE)	211.6	199.4	189.7	134.4	185.0	184.0	49.0	25.3	19.9	31.8	47.87	34.78	217.3	237.3	215.6	155.7	230.1	211.2
I_2 - (0.6 IW/CPE)	194.2	186.6	177.9	130.8	174.3	172.7	46.5	23.6	19.2	31.1	48.83	33.92	199.3	208.0	198.6	150.6	236.9	198.7
I_3 - (0.4 IW/CPE)	229.1	159.17	163.5	127.7	154.5	166.8	53.2	23.4	18.7	30.7	43.00	33.81	234.6	196.3	191.9	151.3	214.2	193.7
S.Em.±	13.04	3.790	1.639	3.130	3.736	6.191	3.13	0.839	0.107	0.436	0.75	1.040	13.34	2.716	1.647	2.860	3.954	4.614
C.D. (0.05)	NS	14.882	6.435	NS	14.736	NS	NS	NS	0.420	NS	3.081	NS	NS	10.667	6.467	NS	15.526	NS
Sub- INM Treatments																		
F_1 - RDF	211.0	184.98	181.2	130.2	163.8	174.2	48.9	24.8	19.2	31.5	44.98	34.02	209.5	214.1	203.9	152.0	218.4	199.6
F_2 - RDF + BF (*Azospirillum* + PSB)	245.8	198.28	189.2	137.7	183.6	190.9	50.7	26.2	20.4	33.4	51.21	36.36	243.9	234.2	216.1	160.7	245.4	220.0
F_3 - RDF + BF + GM (one row of sunhemp between two rows of maize)	283.9	232.90	215.9	151.6	207.6	218.4	62.0	29.1	21.2	34.7	55.54	40.51	296.6	265.9	236.9	169.4	263.5	239.8
F_4 - 75% RDF + Maize stalk incorporation with cellulolytic culture +BF+ GM	173.1	164.46	167.1	122.4	157.3	156.9	45.8	21.5	18.2	29.2	43.34	31.61	181.3	192.3	195.0	145.6	215.5	185.9
F_5 - 50% RDF + Maize stalk incorporation with cellulolytic culture+ BF+GM	144.4	127.98	131.8	112.8	144.0	132.2	40.4	18.8	17.4	27.3	37.75	28.36	154.0	162.9	158.3	134.9	192.8	160.6
S.Em.±	5.15	5.843	2.678	3.013	3.381	4.312	1.01	1.749	0.121	0.679	1.612	0.773	5.65	3.431	1.825	2.231	8.560	4.168
C.D. (0.05)	15.02	17.054	7.817	8.794	9.868	12.258	2.93	5.094	0.354	1.982	4.706	2.198	16.50	10.015	5.326	6.152	24.984	11.846
Interaction (Irrigation levels x INM treatments)																		
S.Em.±	15.30	9.813	4.638	5.620	6.433	9.108	3.50	2.831	0.216	1.139	2.618	1.587	16.00	5.969	3.160	4.486	13.837	7.936
C.D. (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

RDF-Recommended dose of fertilizer, BF- Biofertilizers, GM- Green manure, NS- Non-significant

F_1(N- 174.2 kg ha^{-1}, P- 34.02 kg ha^{-1} and K- 199.6 kg ha^{-1}), F_4(N- 156.9 kg ha^{-1}, P- 31.61 kg ha^{-1} and K- 185.5 kg ha^{-1}) and F_5 (N- 132.2 kg ha^{-1}, P- 28.36 kg ha^{-1} and K- 160.6 kg ha^{-1}). Higher nutrient availability in soil has supported maize crop for higher uptake of nutrients and production of grain and fodder yield of maize.

During fifth year, uptake of N, P and K by maize at 75% RDF plus maize stalk incorporation with cellulolytic culture plus biofertilizer with one row of sunhemp between two rows of maize (N- 157.3, P- 43.34 and K- 215.5 kg ha^{-1}) was on par with 100% recommended dose of fertilizer (N- 163.8, P- 44.98 and K- 218.4 kg ha^{-1}). Similar results due to application of 75% RDF and 25% N through *Leucaena* loppings + biofertilizer was obtained by Gable *et al.* (2008). Uptake of N, P and K was not found significant with respect to irrigation levels.

Significant increase in organic carbon (0.46 to 0.67%) content due to INM treatments was observed (Table 4). The increased level of organic carbon is a good indication of better carbon sequestration in soil due to incorporation of maize stalks which otherwise increased the CO_2 level of atmosphere due to burning of maize stalks. The data in respect of status of available NPK in soil after harvest of crop indicated that, application of recommended dose of fertilizer + one row of sunhemp between two rows of maize + biofertilizer recorded highest available nitrogen (208.9 kg ha^{-1}) in soil (Table 4). Increase in available nitrogen might be due to contributions of biofertilizer, sunhemp and maize stalk to the available nitrogen in the soil. The increase in available nitrogen due to organic materials application could also be attributed to the greater multiplication of soil microbes, which must have converted organically bound nitrogen to inorganic form. Similar trend was also observed with available phosphorus (31.0 kg ha^{-1}) and potassium (815.1 kg ha^{-1}). This might be due to slow decomposition of organic matter producing acids which in turn increased the availability of nutrients. Increase in available phosphorus might be due to increase of organic matter which enhanced activity of phosphorus solubilizing microorganisms. Increase in available potassium due to maize stalk and sunhemp application might be attributed *t*o the direct addition of potassium to the available pool of the soil besides the reduction in potassium fixation and release of potassium due to the interaction of organic matter with clay. Similarly, Singh and Totawat (2002) reported that integrated use of organic manures with chemical fertilizer significantly increased available N, P and K status after harvest of maize.

Integrated nutrient management study on yield and uptake of nutrients in maize indicated that, application of RDF plus biofertilizer with one row of sunhemp between two rows of maize significantly increased the maize grain and fodder yield besides increased uptake of N, P and K nutrients. Further, grain yield of maize and uptake of N, P and K with 75% RDF plus maize stalk incorporation with cellulolytic culture plus biofertilizer and one row of sunhemp between two rows of maize was on par with 100% RDF, indicating stabilization of yield from fifth year due to stabilization of 25% of RDF with organics and biofertilizer. Adopting INM practices improves significantly organic carbon content in soils and increases the availability of nutrients.

Table 4. Effect of INM treatments and irrigation levels on soil properties after five years of experiment

Treatment	pH	EC (dS m^{-1})	O.C (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Main: Irrigation levels(I)						
I_1 - (0.8 IW/CPE)	8.23	0.27	0.62	189.1	27.0	752.9
I_2 - (0.6 IW/CPE)	8.21	0.27	0.60	186.2	26.1	721.5
I_3 - (0.4 IW/CPE)	8.18	0.26	0.57	185.1	25.7	712.1
S.Em.±	0.015	0.003	0.006	0.258	0.125	2.302
C.D. at 5%	0.058	0.0013	0.023	1.014	0.490	9.040
Sub:INM treatments						
F_1- RDF	8.33	0.31	0.46	179.6	25.0	709.8
F_2- RDF + BF (*Azospirillum* + PSB)	8.23	0.26	0.55	181.1	26.3	724.8
F_3- RDF + BF + GM (one row of sunhemp between two rows of maize)	8.11	0.22	0.65	208.9	31.0	815.1
F_4- 75% RDF + Maize stalk incorporation with cellulolytic culture +BF+ GM	8.21	0.26	0.67	184.9	24.9	703.3
F_5- 50% RDF + Maize stalk incorporation with cellulolytic culture+ BF+GM	8.17	0.25	0.66	179.4	24.1	691.1
S.Em.±	0.013	0.003	0.006	1.148	0.177	3.986
C.D. at 5%	0.038	0.008	0.018	3.350	0.518	11.635
Interaction (Irrigation levels x INM treatments)						
S.Em.±	0.123	0.005	0.011	1.797	0.302	6.590
C.D. at 5%	NS	NS	NS	NS	NS	NS

RDF-Recommended dose of fertilizer, BF- Biofertilizers, GM- Green manure, NS- Non-significant

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