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Impact of organic and inorganic nutrient sources on nutrient concentration and their uptake by maize (*Zea mays* L.)

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Abstract
Soil quality deterioration, especially in intensive cropping system has become a serious problem for crop productivity. Consequently, strategies for sustainable crop production and soil health are urgently required. Therefore, a field experiment was conducted to study the effect of organic and inorganic nutrient sources on nutrient content and their uptake by maize crop during two consecutive *kharif* seasons of years 2019 and 2020, respectively. The experiment was laid out in randomized block design (RBD) assigning eight treatments of organic and inorganic nutrient sources comprising of (T_1) RDF (120:60:40 kg $N:P_2O_5:K_2O$ ha^{-1}), (T_2) RDF + Zn, (T_3) RDF + S, (T_4) RDF + Zn + S, (T_5) RDF + VC (5 t ha^{-1}), (T_6) RDF + VC (10 t ha^{-1}), (T_7) RDF + VC (10 t ha^{-1}) and (T_8) RDF + FYM (10 t ha^{-1}) and were replicated thrice.
The results reported that the higher nutrient concentration *viz*. nitrogen, phosphorous and potassium were recorded under application of RDF + FYM (10 t ha^{-1}) during both the year. In case of sulphur, significantly higher content was noted due to application of RDF + Zn + S which was statistically at par with RDF + S during both the experimental years. While, higher zinc content was observed due to application of RDF + Zn + S which was statistically at par with RDF + Zn during both the experimental years. Whereas, nutrient uptake was also higher in similar treatment.

Keywords: Grain, stover, sulphur, inorganic, zinc and maize

Introduction
Among the various cereals namely rice and wheat have been under the main focus for achieving food security. However, maize has emerged as the third most important cereal crop after rice and wheat (Paramasivan *et al.*, 2010) [12]. It is the staple food for vast rural population of our country. Maize (*Zea mays* L.) has high genetic potential than any other cereals crops. Hence, it is known as "miracle crop" and also as "queen" of cereals (Singh *et al.*, 2017) [15]. Maize is an annual plant which belongs to family Gramineae. It is the American Indian word for corn which means 'to sustain life'. It is cultivated globally as one of the most important cereal crops. It is a versatile crop grown over a range of agro climatic zones and provides food, feed, fodder and serves as sources of basic raw material for the number of industrial products *viz.*, starch, protein, oil, alcoholic beverages, food sweeteners, cosmetics, more recently as bio-fuel etc. No other cereal is being used in as many ways as maize. It occupies an important place as a source of human food (25%), animal feed (12%), poultry feed (49%), starch (12%) and 1% each in brewery and seed.
The most important aspects of getting good yield of maize is the proper nutrient management. Maize is a heavy feeder crop and its productivity is mainly dependent on nutrient management. The adequate and balanced supply of plant nutrients is of critical importance in improving the productivity of crops. Chemical fertilizers are considered as the primary source of plant nutrients. But the soils which received nutrients only through chemical or synthetic fertilizers are shoeing declining productivity despite of being supplied with sufficient nutrients. Chemical fertilizers no doubt have boosted the crop growth and yield, but to a large extent these have contributed to deterioration of soil physical, chemical and biological condition (Mehta *et al.*, 2005) [11]. Excessive use of chemical fertilizers has been associated with decline in soil physical and chemical properties and crop yield (Kumar *et al*., 2016) [8] and significant land problem such as degradation due to over exploitation of land, soil pollution caused by high application rate of fertilizer and pesticide application (Singh *et al*., 2000) [14]. Excessive soil degradation, high fertilizer cost and low purchasing power of the farming community leads to rethink about alternatives.

Unlike chemical fertilizers, organic manure is available at lower price. Organic manure because of their low nutrient content cannot fulfill country's requirement for crop production. Therefore, a combination of organic manures with chemical fertilizers in the form of integrated manure appears to be best alternatives (Srinivasrao *et al*., 2003) [16]. Application of both organic and inorganic fertilizers not only increases the crop yield also to maintain the soil physical, chemical and biological conditions. The organic sources besides supplying N, P and K also make unavailable sources of elemental nitrogen, bound phosphates and micronutrients into available form to facilitate plant to absorb the nutrients.

However, information regarding organic and inorganic nutrient sources in maize production in Uttar Pradesh is lacking. Keeping in view the above discussed facts of sufficient information and sparce related research, the present investigation was undertaken to find out the effect of organic and inorganic nutrient sources in maize under Ghazipur conditions.

Material and Methods

The experiment was conducted during two consecutive *kharif* seasons of years 2019 and 2020, respectively at Farmers field of Village Tulsipur, Post- Bikrampur, Ghazipur, Uttar Pradesh, situated at latitude of 25° 36' North and longitude of 83° 09' East. The total rainfall of 780.1 and 1140.3 mm were received during crop growing season of year, 2019 and 2020, respectively. Soil of the experiment field had sandy loam in texture, slightly alkaline in reaction, low in electrical conductivity, low in organic carbon, available nitrogen and medium in available phosphorus and potassium.

The experiment was laid out in randomized block design (RBD) assigning eight treatments of organic and inorganic nutrient sources comprising of (T_1) RDF (120:60:40 kg $N:P_2O_5:K_2O$ ha^{-1}), (T_2) RDF + Zn, (T_3) RDF + S, (T_4) RDF + Zn + S, (T_5) RDF + VC (5 t ha^{-1}), (T_6) RDF + VC (10 t ha^{-1}), (T_7) RDF + VC (10 t ha^{-1}) and (T_8) RDF + FYM (10 t ha^{-1}) and were replicated thrice. The soil of the experimental field was sandy clay loam in texture having slightly alkaline in reaction (pH 7.21 & 7.20), low in organic carbon (0.36 & 0.37%) and available nitrogen (174.96 & 185.29 kg ha^{-1}), but medium in available phosphorus (20.13 & 20.69 kg ha^{-1}) and potassium (192.06 & 216.98 kg ha^{-1}) during first and second year, respectively. Sulphur and zinc nutrition (Each 25 kg ha^{-1}) through elemental sulphur and chelated zinc, respectively were applied as basal dose during both the experimental years. Nitrogen was applied 50% as basal and remaining in two equal splits. Maize variety "Azad Kamal" were used for the investigations. Nutrient concentration and their uptake were analysed as per standard procedure. The data relating to each character were analyzed as per the procedure of analysis of variance and significance was tested by "F" test (Gomez and Gomez 1984) [5].

Results and Discussions

Nutrient content

Data revealed (Table 1) that nitrogen content in grain and stover showed marked variation due to organic and inorganic nutrient sources. Significantly higher nitrogen content in grain (1.919 and 1.923%) and stover (0.724 and 0.729%) was noted due to application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. However, least nitrogen content in both grain as well as stover was noted in application of RDF (120:60:40 $N:P_2O_5:K_2O$ ha^{-1}).

Results depicted in Table 1 that significantly higher phosphorous content in grain (0.380 and 0.386%) and stover (0.164 and 0.168%) was observed due to application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. Least, phosphorous content in grain and stover was found with application of RDF (120:60:40 $N:P_2O_5:K_2O$ ha^{-1}).

It is clear from the data in Table 2 that significantly higher potassium content in grain (0.444 and 0.449%) and stover (1.099 and 1.106%) was observed in application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. However, least potassium content in grain and stover was found with application of RDF (120:60:40 $N:P_2O_5:K_2O$ ha^{-1}) during both the years.

This was due to combined use of organic manure and chemical fertilizer has been found to be providing not only in maintaining higher productivity but also in providing stable crop yields for sustainable crop production through organic manure and balanced use of chemical fertilizers. These are in confirmation with findings of Sujata *et al*. (2008) [17]; Behera and Singh (2009) [1]; Dadarwal *et al*. (2009) [2]; Das *et al*. (2010) [3]; Sharma and Banik (2012) [13].

Data revealed (Table 2) that sulphur content in grain and stover showed marked variation due to organic and inorganic nutrient sources. Significantly higher sulphur content in grain (0.541 and 0.552%) and stover (0.249 and 0.262%) was noted due to application of RDF + Zn + S which was statistically at par with RDF + S during both the experimental years. However, least sulphur content in both grain as well as stover was noted with application of RDF (120:60:40 $N:P_2O_5:K_2O$ ha^{-1}).

Data showed in Table 3 that significantly higher zinc content in grain (63.19 and 63.08 mg kg^{-1}) and stover (24.52 and 25.61 mg kg^{-1}) was observed due to application of RDF + Zn + S which was statistically at par with RDF + Zn during both the experimental years. This might be due to greater availability in soil environment and enhanced translocation in plant system. Goyal (2002) [6] reported that addition of S + Zn to NPK in balanced proportion or at recommended level enhanced efficiency of each other, thus maintained synergistic interaction. Moreover, increase in shoot growth as evident from higher accumulation of dry matter under the influence of balanced and higher level of fertilization. Further, it has been reported that shoot and root growth mutually enhanced the efficiency of plants, as evident from higher grain and stover yield which might have supplied adequate metabolites for root growth and its functional activity, this might have helped in greater extraction of other nutrients like K, S and Zn resulting in enhancement in their status (Gardner *et al*., 1986) [4]. Increase in nutrient concentration with balanced fertilization seems to be affected by greater mobilization of nutrients from vegetative parts to grain.

Nutrient uptake

It is apparent from the data in Table 4 that significantly higher nitrogen uptake by grain (71.08 & 73.44 kg ha^{-1}), stover (57.67 & 58.41 kg ha^{-1}) and total (128.75 & 131.85 kg ha^{-1}) were recorded with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years.

Results showed in Table 5 showed that the organic and inorganic nutrient sources caused significantly higher phosphorous uptake by grain (14.08 & 14.74 kg ha^{-1}), stover (13.06 & 13.46 kg ha^{-1}) and total (27.14 & 28.20 kg ha^{-1}) were observed with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. However, least phosphorous uptake by grain and stover as well as total was found with application of RDF (120:60:40 N:P_2O_5:K_2O ha^{-1}) during both the years.

Among the different organic and inorganic nutrient sources (Table 6), significantly highest potassium uptake by grain (16.45 and 17.15 kg ha^{-1}), stover (87.55 and 88.61 kg ha^{-1}) as well as total uptake (103.99 and 105.76 kg ha^{-1}) was recorded in application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. However, least potassium uptake by grain and stover as well as total was found with application of RDF (120:60:40 N:P_2O_5:K_2O ha^{-1}) during both the years.

Data on sulphur uptake showed marked variation due to organic and inorganic nutrient sources during both the years (Table 7). Significantly higher sulphur uptake by grain (17.89 & 18.79 kg ha^{-1}) was noted with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + Zn + S during first year and with application of RDF + FYM (10 t ha^{-1}) during second year of experimentation. In case of stover, significantly higher sulphur uptake (17.10 & 18.11 kg ha^{-1}) was recorded with application of RDF + Zn + S and being at par with RDF + VC (10 t ha^{-1}) and RDF + S during both the years of investigation. Significantly higher values of total sulphur uptake (34.70 & 36.10 kg ha^{-1}) was exerted with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + Zn + S and RDF + S during both the years. While, least sulphur uptake was recorded with application of RDF (120:60:40 N:P_2O_5:K_2O ha^{-1}) during both the years.

Among the different organic and inorganic nutrient sources (Table 8), significantly highest zinc uptake by grain (223.28 and 230.40 g ha^{-1}) was recorded in application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) during both the experimental years. Stover uptake also showed significant effect on zinc uptake and significantly higher zinc uptake (168.96 g ha^{-1}) was noted with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + Zn + S and RDF + FYM (10 t ha^{-1}) during first year of experimentation. In second year of experimentation, significantly higher zinc uptake (177.02 g ha^{-1}) by stover was noted with application of RDF + Zn + S which was statistically at par with RDF + VC (10 t ha^{-1}) and RDF + FYM (10 t ha^{-1}). In case of highest total zinc uptake (392.24 and 400.74 g ha^{-1}) by grain as well as stover was observed with application of RDF + VC (10 t ha^{-1}) which was statistically at par with RDF + FYM (10 t ha^{-1}) and RDF + Zn + S during both the experimental years. However least zinc uptake was recorded with application of RDF (120:60:40 N:P_2O_5:K_2O ha^{-1}) during both the years.

The nutrient uptake by the crop is largely dependent on biological yield and concentration of nutrient in plant at cellular level. The improvement in uptake of nutrients under application of RDF + VC (10 ha^{-1}) and being at par with RDF + FYM (10 ha^{-1}) could be ascribed to increase in the aforesaid factors contributing to the uptake of nutrients by the crop. The uptake of nutrients usually follows the yield pattern the amount of nutrient taken up per unit amount of biomass production determine the yields, since the essential nutrients are involved in the metabolism of the plants. The results confirm the findings of Meena *et al.* (2006) [10]; Kumar (2008) [7]; Makinde and Ayoola (2010) [9].

Table 1: Nitrogen and phosphorous content (%) influenced by different organic and inorganic nutrient sources at harvest in maize crop

Treatments		Nitrogen content (%)				Phosphorous content (%)			
		Grain (%)		Stover (%)		Grain (%)		Stover (%)	
		2019	2020	2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	1.502	1.509	0.518	0.520	0.342	0.345	0.137	0.138
T_2	RDF + Zn	1.521	1.525	0.551	0.554	0.355	0.357	0.144	0.146
T_3	RDF + S	1.556	1.558	0.564	0.566	0.357	0.359	0.148	0.151
T_4	RDF + Zn + S	1.657	1.660	0.587	0.590	0.361	0.364	0.150	0.152
T_5	RDF + VC (5 t ha^{-1})	1.824	1.828	0.690	0.694	0.372	0.373	0.156	0.159
T_6	RDF + VC (10 t ha^{-1})	1.919	1.900	0.724	0.729	0.370	0.386	0.164	0.168
T_7	RDF + FYM (5 t ha^{-1})	1.820	1.825	0.679	0.682	0.366	0.368	0.153	0.155
T_8	RDF + FYM (10 t ha^{-1})	1.876	1.881	0.711	0.708	0.374	0.378	0.160	0.163
S.Em±		0.016	0.017	0.010	0.011	0.003	0.004	0.002	0.002
CD at 5%		0.051	0.053	0.031	0.033	0.010	0.012	0.007	0.008

Table 2: Potassium and sulphur content (%) influenced by different organic and inorganic nutrient sources at harvest in maize crop

Treatments		Potassium content (%)				Sulphur content (%)			
		Grain (%)		Stover (%)		Grain (%)		Stover (%)	
		2019	2020	2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	0.379	0.380	1.022	1.023	0.379	0.384	0.159	0.164
T_2	RDF + Zn	0.405	0.407	1.055	1.057	0.401	0.413	0.174	0.183
T_3	RDF + S	0.408	0.410	1.061	1.062	0.536	0.543	0.241	0.256
T_4	RDF + Zn + S	0.411	0.414	1.067	1.069	0.541	0.552	0.249	0.262
T_5	RDF + VC (5 t ha^{-1})	0.444	0.446	1.079	1.081	0.476	0.485	0.205	0.209
T_6	RDF + VC (10 t ha^{-1})	0.440	0.449	1.099	1.106	0.483	0.492	0.211	0.216
T_7	RDF + FYM (5 t ha^{-1})	0.421	0.424	1.075	1.077	0.441	0.454	0.189	0.193
T_8	RDF + FYM (10 t ha^{-1})	0.435	0.439	1.090	1.093	0.452	0.464	0.197	0.202
S.Em±		0.005	0.006	0.006	0.006	0.005	0.006	0.002	0.003
CD at 5%		0.016	0.018	0.018	0.019	0.017	0.018	0.008	0.009

Table 3: Zinc content (mg kg^{-1}) influenced by different organic and inorganic nutrient sources at harvest in maize crop

Treatments		Zinc content (mg kg^{-1})			
		Grain (mg kg^{-1})		Stover (mg kg^{-1})	
		2019	2020	2019	2020
T_1	RDF (120:60:40)	55.29	55.44	19.27	19.32
T_2	RDF + Zn	63.08	64.12	24.43	25.54
T_3	RDF + S	57.51	57.63	19.68	19.74
T_4	RDF + Zn + S	63.19	64.27	24.52	25.61
T_5	RDF + VC (5 t ha^{-1})	60.39	60.68	20.49	20.52
T_6	RDF + VC (10 t ha^{-1})	60.28	60.75	21.21	21.26
T_7	RDF + FYM (5 t ha^{-1})	58.57	58.63	20.37	20.44
T_8	RDF + FYM (10 t ha^{-1})	59.67	59.74	21.04	21.11
S.Em±		0.882	0.903	0.346	0.370
CD at 5%		2.651	2.712	1.045	1.118

Table 4: Nitrogen uptake (kg ha^{-1}) by maize crop influenced different organic and inorganic nutrient sources at harvest

Treatments		Nitrogen uptake (kg ha^{-1})					
		Grain uptake		Stover uptake		Total uptake	
		2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	37.94	39.19	31.67	32.38	69.61	71.56
T_2	RDF + Zn	41.75	42.73	35.57	36.42	77.32	79.15
T_3	RDF + S	45.14	46.23	37.53	37.57	82.67	83.79
T_4	RDF + Zn + S	49.94	51.28	40.30	40.78	90.25	92.06
T_5	RDF + VC (5 t ha^{-1})	58.59	60.18	49.97	50.68	108.56	110.86
T_6	RDF + VC (10 t ha^{-1})	71.08	73.44	57.67	58.71	128.75	131.85
T_7	RDF + FYM (5 t ha^{-1})	56.62	58.89	47.60	48.65	104.22	107.55
T_8	RDF + FYM (10 t ha^{-1})	67.18	69.77	54.27	55.61	121.45	125.37
S.Em±		2.04	2.27	1.67	1.72	3.74	4.02
CD at 5%		6.12	6.84	5.03	5.16	11.26	12.09

Table 5: Phosphorous uptake (kg ha^{-1}) by maize crop influenced different organic and inorganic nutrient sources at harvest

Treatments		Phosphorous uptake (kg ha^{-1})					
		Grain uptake		Stover uptake		Total uptake	
		2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	8.64	8.96	8.37	8.59	17.01	17.55
T_2	RDF + Zn	9.74	10.00	9.30	9.60	19.04	19.60
T_3	RDF + S	10.36	10.65	9.85	10.02	20.20	20.67
T_4	RDF + Zn + S	10.88	11.24	10.30	10.51	21.18	21.75
T_5	RDF + VC (5 t ha^{-1})	14.25	14.78	11.30	11.61	23.15	23.89
T_6	RDF + VC (10 t ha^{-1})	14.08	15.04	13.06	13.46	27.14	28.20
T_7	RDF + FYM (5 t ha^{-1})	11.39	11.88	10.73	11.06	22.11	22.93
T_8	RDF + FYM (10 t ha^{-1})	13.39	14.02	12.39	12.80	25.78	26.82
S.Em±		0.46	0.50	0.38	0.41	0.77	0.82
CD at 5%		1.38	1.51	1.16	1.24	2.32	2.46

Table 6: Potassium uptake (kg ha^{-1}) by maize crop influenced by different organic and inorganic nutrient sources at harvest

Treatments		Potassium uptake (kg ha^{-1})					
		Grain uptake		Stover uptake		Total uptake	
		2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	9.57	9.87	62.47	63.69	72.05	73.56
T_2	RDF + Zn	11.12	11.40	68.10	69.49	79.22	80.89
T_3	RDF + S	11.84	12.16	70.60	70.48	82.44	82.65
T_4	RDF + Zn + S	12.39	12.79	73.26	73.89	85.65	86.68
T_5	RDF + VC (5 t ha^{-1})	13.68	14.09	78.14	78.95	91.82	93.04
T_6	RDF + VC (10 t ha^{-1})	16.45	17.15	87.55	88.61	103.99	105.76
T_7	RDF + FYM (5 t ha^{-1})	13.10	13.68	75.37	76.83	88.47	90.52
T_8	RDF + FYM (10 t ha^{-1})	16.08	16.38	84.39	85.84	99.97	102.13
S.Em±		0.50	0.54	2.61	2.65	3.22	3.37
CD at 5%		1.51	1.63	7.83	7.96	9.68	10.12

Table 7: Sulphur uptake (kg ha^{-1}) by maize crop influenced by different organic and inorganic nutrient sources at harvest

Treatments		Sulphur uptake (kg ha^{-1})					
		Grain uptake		Stover uptake		Total uptake	
		2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	9.57	9.97	9.72	10.21	19.29	20.18
T_2	RDF + Zn	11.01	11.57	11.23	12.03	22.24	23.60
T_3	RDF + S	15.55	16.11	16.04	16.99	31.59	33.10
T_4	RDF + Zn + S	16.31	17.05	17.10	18.11	33.40	35.16
T_5	RDF + VC (5 t ha^{-1})	15.13	15.97	14.85	15.26	29.97	31.23
T_6	RDF + VC (10 t ha^{-1})	17.89	18.79	16.81	17.31	34.70	36.10
T_7	RDF + FYM (5 t ha^{-1})	13.72	14.65	13.25	13.77	26.97	28.42
T_8	RDF + FYM (10 t ha^{-1})	16.19	17.21	15.25	15.87	31.44	33.07
S.Em±		0.54	0.57	0.55	0.57	1.05	1.09
CD at 5%		1.64	1.71	1.67	1.73	3.16	3.28

Table 8: Zinc uptake (g ha^{-1}) by maize crop influenced by different organic and inorganic nutrient sources at harvest

Treatments		Zinc uptake (g ha^{-1})					
		Grain uptake		Stover uptake		Total uptake	
		2019	2020	2019	2020	2019	2020
T_1	RDF (120:60:40)	139.66	143.98	117.80	120.29	257.46	264.26
T_2	RDF + Zn	173.15	179.66	157.70	167.90	330.85	347.56
T_3	RDF + S	166.84	170.99	130.95	131.01	297.79	302.00
T_4	RDF + Zn + S	190.45	198.53	168.35	177.02	358.81	375.55
T_5	RDF + VC (5 t ha^{-1})	190.12	195.35	148.39	149.86	338.51	345.20
T_6	RDF + VC (10 t ha^{-1})	223.28	230.40	168.96	170.34	392.24	400.74
T_7	RDF + FYM (5 t ha^{-1})	182.21	189.20	142.81	145.82	325.03	335.02
T_8	RDF + FYM (10 t ha^{-1})	213.68	221.58	162.89	165.80	376.57	387.37
S.Em±		6.72	7.08	5.28	5.39	11.58	11.83
CD at 5%		20.18	21.24	15.87	16.17	34.76	35.51

Conclusions
From the above overall study, it is recommended that to obtain higher nutrient concentration and their uptake of maize should be grown by combined application of RDF + VC (10 t ha^{-1}) under ago-climatic conditions of Ghazipur region of Eastern Uttar Pradesh.

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