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Sorghum Yield and Nutrient Uptake under Long Term Nutrient Management Practices in Sorghum-Sunflower Cropping System in an Alfisol

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Abstract

The long term fertilizer experiment which was initiated in 1999, was monitored during *kharif* 2013 to study the effect of different nutrient management practices under sorghum-sunflower cropping system in an Alfisol to study the sorghum yields and nutrient uptake by sorghum. Integrated nutrient management practice by applying optimum NPK fertilizers along with FYM (NPK+FYM) or crop residues (NPK+CR) increased the sorghum grain yield significantly over application of only fertilizers (100% NPK). The sorghum yield significantly increased with increasing levels of NPK only up to 100% NPK. Super optimal dose of fertilizers (150% NPK) did not increase the yield. Continuous application of only nitrogen resulted in reduced yields due to the imbalanced use of fertilizers. Additional application of phosphorus significantly increased the yield while there was no significant yield increase with application of potassium, sulphur, boron or zinc. Application of phosphorus, potassium and zinc significantly increased their uptake by the crop but application of nitrogen or sulphur did not increase their uptake.

Highlights :

Integrated nutrient management practice by applying FYM or crop residues along with optimum NPK fertilizers (NPK+FYM and NPK+CR) increased the sorghum grain yield and nutrient uptake significantly over application of only fertilizers (100% NPK). Among the graded levels of NPK, sorghum yield increased only up to 100% NPK. Super optimal dose of fertilizers (150% NPK) did not increase the yield.

Keywords: Fertilizer, *kharif,* sorghum, NPK fertilizers

Continuous application of fertilizers and manures influence various physical, physico-chemical, chemical and biological properties of the soil. The changes in soil properties that occur due to continuous use of fertilizers and manures assume great significance for sustainability of the cropping system. Changes in the soil fertility caused by the imbalanced use of fertilizers and continuous use of high analysis fertilizers without organic manures lead to problems like declining organic matter and mining of nutrients especially those which are not applied in sufficient quantities. The long term experiments offer a unique opportunity to test the relevance of these concepts in different cropping systems. The long term experiments provide insights into the consequences of land management strategies that cannot be obtained through other means (Lal and Stewart, 1995). The long term fertilizer experiment of the Indian Institute of Oilseed Research, Rajendranagar, Hyderabad, initiated in 1999 was monitored during *kharif* 2013 to study the effect of different nutrient management practices under sorghum-sunflower cropping system in an Alfisol on sorghum yields and nutrient uptake by sorghum.

Materials and Methods

The present study was conducted during *kharif* 2013 at research farm of Indian Institute of Oilseed Research (IIOR), Rajendranagar, Hyderabad. At initiation in 1999 the soil was sandy loam in texture and slightly alkaline (pH 7.20) in reaction, non saline in nature (EC 0.08 dS m^{-1}) and medium in organic carbon content (0.52%). The soil was medium in available nitrogen (242 kg ha^{-1}) and available phosphorus (13.3 kg P ha^{-1}) and high in available potassium (319 kg K ha^{-1}). Available zinc content (1.0 mg kg^{-1}) was above critical level (0.6 mg kg^{-1}). The experiment was laid out in randomized block design with 12 treatments (Table 1) and three replications. The treatments consisted of different combinations of fertilizers, manures and a control. The optimum NPK *i.e.*, 100% NPK (60-30-30 kg N-P_2O_5-K_2O ha^{-1}) was fixed at the initiation of experiment and same layout and treatments are being followed till date. Sorghum variety CSH-14 was taken up in *kharif* 2013. Grain and stover yields were recorded separately for each plot. Plot-wise grain and stover samples collected were analyzed for nutrient content following standard procedures (Piper, 1966). The uptake of nutrients was calculated using the nutrient contents and yields of grain and stover using the following relation for major nutrients:

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient content (\%)} \times \text{yield (kg ha}^{-1}\text{)}}{100}$$

For calculation of the uptake of micronutrients, the following relation was used:

Nutrient uptake (g ha^{-1}) =

$$\frac{\text{Nutrient content (mg kg}^{-1}\text{)} \times \text{yield (kg ha}^{-1}\text{)}}{1000}$$

Results and Discussion

Grain and Stover yield

Grain and stover yield of sorghum in *kharif* 2013 are presented in table 2. The grain and stover yield of sorghum ranged from 3.73 to 32.69 q ha^{-1} and 18.45 to 35.65 q ha^{-1}, respectively. Application of 100% NPK along with FYM @ 5 t ha^{-1} resulted in grain yield of 32.69 q ha^{-1} which was significantly higher than all the other treatments, except NPK+CR (30.52 q ha^{-1}). The grain yield with NPK+FYM and NPK+CR was significantly higher than that with application of only fertilizers *i.e.*, treatment 100% NPK (25.75 q ha^{-1}). Integrated nutrient management practice by applying FYM or crop residues along with optimum (100%) NPK fertilizers thus proved beneficial in increasing the yield significantly over application of only fertilizers. Application of NPK+FYM resulted in higher yields as compared to all other treatments which could be due to higher nutrient uptake and improvement of soil environment (Krishna *et al.* 2007 and Humne *et al.* 2008). As FYM adds appreciable amounts of macro and micro nutrients and FYM has a significant positive role in improving the soil fertility, its application along with 100% NPK resulted in increasing the yield. Similar results in long term experiments were also reported by Verma *et al.* (2011) and Selvi *et al.* (2005). There was an increase in grain yield over control (3.73 q ha^{-1}) with 50% NPK (20.69 q ha^{-1}) and further increase with 100% NPK (25.75 q ha^{-1}). But, application of super optimal dose of NPK *i.e.*, 150% NPK (25.59 q ha^{-1}) did not increase the yield over 100% NPK. Similar trends of yield was reported for *kharif* crops in long term trials in rice-wheat cropping system by Manna *et al.* (2005) and Singh *et al.* (2006) and in rice-rice cropping system by Srilatha *et al.* (2014).

The grain yield with application of nitrogen alone (T_1, 100% N, 7.89 q ha^{-1}) was on par with that in control (3.73 q ha^{-1}). Application of nitrogen along with phosphorus (T_2, NP, 27.45 q ha^{-1}) or along with phosphorus and potassium (T_3, NPK, 25.75 q ha^{-1}) increased the grain yield significantly over application of N alone. Continuous imbalanced application with only nitrogen to every crop thus resulted in reduced yields compared to balanced nutrition. Application of only urea (to supply N), leads to degradation of soil environment and increases concentration of various toxic elements (Sharma *et al.* 1998) emphasizing the need of balanced fertilization. However, continuous application of other nutrients *viz.*, sulphur (T_8), boron (T_9), zinc (T_{10}) or all these three *i.e.*, S+Zn+B (T_{11}) along with 100% NPK to the *rabi* crop in the sequence since initiation of the experiment did not increase the grain yield compared to application of 100% NPK probably due to their availability in sufficient quantities in the soil.

Nutrient uptake

Nitrogen

Uptake of nitrogen by sorghum as influenced by continuous application of fertilizers and manures during *kharif* 2013 is presented in table 3. The nitrogen content in the grain ranged from 1.07% in 50% NPK to 1.34% in 150% NPK. The nitrogen content in sorghum stover ranged from 0.45% in N alone to 1.04% in NPK+FYM.

The nitrogen content in sorghum grain and stover increased progressively with increasing levels of NPK.

The total nitrogen uptake by the sorghum crop (grain + stover) ranged from 15.87 kg ha^{-1} in control to 78.37 kg ha^{-1} in NPK+FYM. Imbalanced fertilization with only N (uptake of 20.07 kg ha^{-1}) did not increase the N uptake over control. Balanced fertilization by adding NPK significantly increased the N uptake by the crop (59.33 kg ha^{-1}) over N alone. Integrated nutrient application of NPK+FYM (uptake of 78.37 kg ha^{-1}) increased the N uptake significantly over application of only NPK. Maheshwara Prasad and Prabhu Prasadini (2013) also reported that integrated nutrient application increased the nitrogen uptake by rice.

Phosphorus

The data pertaining to phosphorous content and uptake by sorghum are presented in table 3. Highest P content was recorded with NPK+FYM (0.55% P in grain and 0.20 in stover) followed by NPK+CR (0.48% P in grain and 0.19% in stover). The phosphorus content of grain increased when P was applied along with N (P content of 0.22% P in NP and only 0.11% N) and addition of K along with NP (0.29% in NPK) increased the P content further. Phosphorus content also increased with increase in level of NPK. It increased from 0.19% in 50% NPK to 0.29% in 100% NPK and 0.40% in 150% NPK.

The lowest total P uptake by sorghum was recorded with control (0.75 kg ha^{-1}) and only N application (1.35 kg ha^{-1}). The P uptake increased with balanced nutrient application *i.e.,* with 100% NPK (9.27 kg ha^{-1}) and 100% NP (7.32 kg ha^{-1}) over application of nitrogen alone (100% N). The P uptake by the crop also increased with increasing NPK levels. The P uptake increased from 0.80 kg ha^{-1} in control to 4.90 kg ha^{-1} in 50% NPK (51% increase). Application of 100% NPK increased it further to 9.27 kg ha^{-1} (89% increase over 50% NPK) and 150% NPK increased it to 15.67 kg ha^{-1} (69% increase over 100% NPK).

The highest P uptake was obtained in the treatment receiving 100% NPK+FYM (24.84 kg ha^{-1}) which was significantly higher than that in all the other treatments including 100% NPK. Sharma *et al.* (2010) also recorded higher total N and P uptake (by rice) with application of 100% NPK+FYM over 100% NPK as FYM was beneficial in enhancing the uptake of both nutrients compared to no organic manure application. Similar results were also reported by Yaduvanshi (2001), Laxminarayana (2006) and Vandana *et al.* (2009).

Potassium

The results on potassium content and uptake by crop are presented in table 3. Potassium content in grain ranged from 0.27% in control and 100% N to 0.33% in NPK+S. Lower potassium content was recorded without addition of K *i.e.,* N (0.27% in grain and 0.64% in stover) and NP (0.28% in grain and 0.83% in stover) than with NPK application (0.30% in grain and 0.99% in stover). Total K uptake by the crop ranged from 13.97 kg ha^{-1} in control to 41.47 kg ha^{-1} in NPK+FYM.

The potassium uptake in NPK+FYM (41.47 kg ha^{-1}) was on par with that in 150% NPK (38.07 kg ha^{-1}) but significantly higher than that in 100% NPK (34.33 kg ha^{-1}). Lower uptake of potassium was recorded in the plots without phosphorus and potassium application *i.e.* in treatment receiving 100% N (14.80 kg ha^{-1}) and in the plots without potassium *i.e.* 100% NP (28.47 kg ha^{-1}) compared to 100% NPK (34.33 kg ha^{-1}). Potassium application along with NP (T_3, NPK) resulted in an increase of about 20.6% in K uptake over NP (T_2). The highest total N, P and K uptake was observed with application of 100% NPK along with FYM (Bhaskar,

Table 1. Treatments details

Treatment No.	Sorghum *(Kharif)*	Sunflower *(Rabi)*
T_1	N	N
T_2	NP	NP
T_3	NPK	NPK
T_4	50% NPK	50% NPK
T_5	150% NPK	150% NPK
T_6	NPK + CR (Crop residue incorporation)	NPK
T_7	NPK+FYM@ 5 t/ha *(Kharif)*	NPK
T_8	NPK	NPK+S@20 kg/ha through gypsum
T_9	NPK	NPK+B@ 1 kg/ha as borax in alternate years
T_{10}	NPK	NPK+limiting micronutrient zinc@ 5kg/ha
T_{11}	NPK	NPK+S+micronutrient (limiting)-Zinc 5 kg/ha
T_{12}	No manures/Fertilizers	No manures/Fertilizers

Table 2. Effect of long term fertilizer and manure application on sorghum grain and stover yield

Trt. No	Treatment	------------- Yield (q/ha) -------------		
		Grain	Stover	Total
1	N	7.89	19.71	27.60
2	NP	27.45	32.01	59.46
3	NPK	25.75	30.82	56.57
4	50% NPK	20.69	32.20	52.89
5	150% NPK	25.59	29.28	54.87
6	NPK+CR	30.52	24.64	55.16
7	NPK+FYM	32.69	33.78	66.47
8	NPK (S)	27.91	33.29	61.21
9	NPK (B)	28.95	31.59	60.54
10	NPK (Zn)	27.36	35.65	63.01
11	NPK (S+B+Zn)	25.52	31.42	56.95
12	Control	3.73	18.45	22.18
	S. Em.(+/-)	2.01	2.22	3.29
	CD (5%)	4.17	4.60	6.82
	CV (%)	10.42	9.26	7.61

2003, Thakur and Sawarkar, 2009 and Vandana *et al.* 2009). This could be due to increased supply of nutrient sources to the crop, as well as due to the indirect effect resulting from reduced loss of organically supplied nutrients and also due to direct addition of an appreciable amount of essential plant nutrients through organic manures (Laxminarayana, 2006). Among the graded levels of fertilizers, potassium uptake increased with increase in level of fertilizer. It was 31.97 with 50% NPK, 38.13 with 100% NPK and 43.97 kg ha^{-1} with 150% NPK.

The above results indicate that due to the poor growth because of P imbalance in T_1 *i.e.* 100% N alone, nutrient (N, P, K) uptake and yield did not increase significantly over control. Application of N and P without potassium (T_2) decreased available potassium from the initial high status (319 kg K ha^{-1}) to medium status (245 kg K ha^{-1}). But application of potassium along with NP (T_3, NPK) did not increase yield or its uptake over NP indicating that K imbalance has not yet set in without K application. But, application of K is recommended to prevent further depletion of available K and emergence of K imbalance in future.

Sulphur

The results on sulphur content and sulphur uptake by sorghum are presented in table 3. Sulphur content in grain ranged from 0.04% in control to 0.10% in NPK+FYM. Sulphur content of grain increased with application of NPK+FYM over only NPK (0.07%). The highest sulphur uptake was obtained with application of 100% NPK+FYM (5.98 kg ha^{-1}) followed by 100% NPK+CR (4.56 kg ha^{-1}). Sulphur uptake in both these treatments was significantly higher than that with application of only NPK (3.87 kg ha^{-1}). The lowest sulphur uptake was recorded in 100% N (1.14 kg ha^{-1}) followed by control (1.23 kg ha^{-1}) and all the other treatments significantly increased the sulphur uptake by the crop over these two treatments.

Zinc

Results on zinc content and uptake by sorghum crop are presented in table 4. Zn content in grain ranged from 10.0 mg kg^{-1} in control to 18.70 mg kg^{-1} in NPK (S+B+Zn). Zinc uptake by the crop ranged from 19.63 g ha^{-1} in control to 93.50 g ha^{-1} in NPK (Zn). Zinc content and uptake of grain and stover and total zinc uptake by the crop increased significantly with application of zinc along with NPK to *rabi* crop (T_{10} and T_{11}) over application of NPK without zinc. The lowest zinc uptake by the crop was recorded in control (19.63 g ha^{-1}) followed by 100% N (20.00 g ha^{-1}) and all the other treatments significantly increased the zinc uptake by the crop. The Zn uptake by the crop increased significantly with application of NPK+FYM (82.50 g ha^{-1}) and NPK+CR (86.40 g ha^{-1}) over application of only NPK (65.67 g ha^{-1}).

Iron

Results on iron content and uptake by sorghum crop are presented in table 4. Iron content in grain ranged from 24.67 mg kg^{-1} in N alone to 47.33 mg kg^{-1} in 150% NPK. Iron uptake by the crop ranged from 45.77 g ha^{-1} in control to 234.98 g ha^{-1} in NPK+CR. All the treatments resulted in significantly higher total Fe uptake by the crop compared to control and only N application. The total uptake by the crop increased significantly over NPK (194.67 g ha^{-1}) with NPK+CR (234.98 g ha^{-1}) and NPK+FYM (217.88 g ha^{-1}).

Table 3. Effect of long term fertilizer and manure application on nitrogen, phosphorus, potassium content and uptake by sorghum crop

Treat-ment	N content (% N)		N uptake (kg/ha)			P content (% P)		P uptake (kg/ha)			K content (% K)		K uptake (kg/ha)			S content (% N)		S uptake (kg/ha)		
	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total
N	1.1	0.58	8.70	11.73	20.07	0.11	0.03	0.84	0.43	1.35	0.27	0.64	2.1	12.70	14.80	0.04	0.04	0.32	0.83	1.14
NP	1.25	0.90	34.4	28.67	63.07	0.22	0.04	6.04	1.28	7.32	0.28	0.83	7.67	26.67	28.47	0.06	0.05	1.55	1.50	3.06
NPK	1.30	0.88	32.10	27.23	59.33	0.29	0.07	7.10	2.17	9.27	0.30	0.99	7.53	30.60	34.33	0.07	0.07	1.81	2.06	3.87
50% NPK	1.07	0.74	22.23	23.93	46.17	0.19	0.03	3.93	0.97	4.90	0.29	0.81	6.0	25.97	31.97	0.06	0.06	1.18	1.91	3.13
150% NPK	1.34	0.93	34.33	27.33	61.67	0.40	0.18	10.3	5.37	15.67	0.30	1.03	7.77	30.30	38.07	0.07	0.09	1.86	2.54	4.40
NPK + CR	1.31	1.02	39.97	25.13	65.10	0.48	0.19	14.75	4.73	19.48	0.31	1.02	9.47	25.13	34.60	0.08	0.09	2.34	2.22	4.56
NPK+ FYM	1.32	1.04	43.13	35.23	78.37	0.55	0.20	17.97	6.87	24.84	0.31	0.93	10.03	31.43	41.47	0.10	0.08	3.17	2.82	5.98
NPK (S)	1.33	0.74	37.10	24.53	61.63	0.30	0.08	8.28	2.66	10.94	0.33	0.87	9.17	28.93	38.10	0.08	0.07	2.21	2.32	4.53
NPK (B)	1.23	0.66	35.60	20.87	56.47	0.23	0.03	6.56	0.95	7.51	0.30	0.89	8.77	28.13	36.90	0.07	0.06	2.03	1.80	3.83
NPK (Zn)	1.20	0.74	32.77	26.50	59.27	0.22	0.05	5.93	1.90	7.83	0.31	0.73	8.57	25.90	34.47	0.06	0.04	1.55	1.54	3.09
NPK (S + B + Zn)	1.15	0.71	29.47	22.40	51.87	0.23	0.03	5.87	0.94	6.81	0.29	0.70	7.50	21.93	29.43	0.07	0.05	1.86	1.47	3.34
Control	1.10	0.64	4.13	11.73	15.87	0.10	0.02	0.47	0.51	0.80	0.27	0.70	1.03	12.93	13.97	0.06	0.05	0.24	0.99	1.23
S. Em. (+/-)	0.01	0.01	2.58	1.63	3.26	0.01	0.01	0.64	0.35	0.75	0.01	0.06	0.68	2.23	2.41	0.01	0.01	0.17	0.26	0.33
CD (5%)	0.02	0.02	5.35	3.38	6.76	0.02	0.02	1.33	0.73	1.56	0.02	0.08	1.41	4.63	5.0	0.02	0.02	0.35	0.54	0.68
CV (%)	1.35	4.36	10.7	8.45	7.5	6.12	11.25	11.16	14.39	9.95	5.50	6.48	11.76	10.89	9.16	9.23	13.6	12.6	12.3	11.5

Table 4. Effect of long term fertilizer and manure application on Zinc, Iron, Manganese and Copper content and uptake by sorghum crop

Treat-ment	Zn content (mg kg^{-1})		Zn uptake (g ha^{-1})			Fe content (mg kg^{-1})		Fe uptake (g ha^{-1})			Mn content (mg kg^{-1})		Mn uptake (g ha^{-1})			Cu content (mg kg^{-1})		Cu uptake (g ha^{-1})		
	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total	Grain	Straw	Grain	Straw	Total
N	15.3	7.67	7.87	14.17	20	24.7	18.3	19.4	36.1	55.50	12.3	12.7	9.70	24.8	34.5	1.0	2.5	0.8	4.9	5.7
NP	12.3	7.58	33.83	24.23	58.07	38.0	22.0	104.3	70.4	174.7	16.0	12.7	43.9	40.5	84.4	2.0	3.2	5.5	10.2	15.7
NPK	15.3	9.0	37.93	27.73	65.67	44.0	27.8	108.9	85.8	194.7	20.0	16.7	49.5	51.4	100.9	2.0	3.3	5.0	10.1	15
50% NPK	13.3	8.0	27.6	25.77	53.37	31.3	20.2	64.9	65.0	129.8	18.0	16.5	37.2	53.1	90.4	1.7	2.6	3.5	8.2	11.7
150% NPK	17.3	13.27	44.27	51.73	83.10	47.3	30.8	121.0	90.3	211.3	21.3	18.3	54.5	53.6	108.1	2.0	4.5	5.1	13.2	18.4
NPK +CR	16.3	10.83	49.8	36.60	86.40	46.0	28.0	140.4	94.6	235.0	20.0	17.7	65.4	59.7	125.1	3.2	3.5	10.5	11.8	22.3
NPK +FYM	17.7	10.0	57.83	24.67	82.50	44.7	29.1	146.2	71.7	217.9	20.7	19.3	63.0	47.5	110.5	2.5	3.0	7.6	7.4	15
NPK (S)	17.3	8.83	48.27	29.37	77.63	42.7	26.2	119.0	87.1	206.2	18.7	16.0	52.2	53.3	105.5	2.0	3.3	5.6	11.1	16.7
NPK (B)	15.3	8.0	44.43	25.27	93.05	35.3	24.5	102.4	77.4	179.8	18.7	17.0	54.1	53.7	107.8	2.0	2.7	5.8	8.5	14.3
NPK (Zn)	18.5	12.0	50.73	42.77	104.63	35.3	21.3	96.7	76.1	172.8	18.7	14.0	51.0	49.9	100.9	2.6	3.7	7.1	13.1	20.2
NPK (S+B+Zn)	18.7	9.67	47.73	30.20	77.93	38.0	26.3	97.0	82.5	179.5	19.3	14.7	49.2	45.9	95.1	2.0	5.0	5.1	15.7	20.8
No Manure	10.0	6.0	5.87	11.77	19.63	31.3	18.4	11.8	34.0	45.80	14.7	11.3	5.30	20.9	26.2	2.0	2.0	0.7	3.7	4.4
S Em. (+/-)	0.45	0.26	3.65	1.74	4.17	0.60	0.10	9.0	5.40	11.10	0.9	0.3	4.30	2.80	5.6	0.1	0.2	0.5	1.0	1.3
CD (5%)	0.93	0.54	7.57	3.63	8.65	1.30	0.20	18.6	11.3	23.0	1.8	0.7	9.0	5.7	11.6	0.2	0.4	1.1	2.1	2.6
CV (%)	3.55	3.43	11.75	7.59	7.78	2.0	0.6	11.6	9.2	8.2	5.8	2.7	11.9	7.3	7.5	4.6	6.8	12.4	12.8	10.2

Manganese

The results on manganese content and uptake by sorghum crop are presented in table 4. Manganese content in grain ranged from 12.30 mg kg^{-1} in N alone to 21.33 mg kg^{-1} in 150% NPK. The total Mn uptake by crop ranged from 26.23 g ha^{-1} in control to 125.07 g ha^{-1} in NPK+CR. All the treatments resulted in significantly higher total Mn uptake by the crop compared to control and only N application. The application of crop residues along with NPK (125.07 g ha^{-1}) significantly increased the Mn uptake over 100% NPK application. There was no significant difference among the balanced fertilizer treatments (T_3, T_8, T_9, T_{10} and T_{11}) in Mn uptake by the crop.

Copper content and uptake

The results on copper content and uptake by sorghum crop are presented in table 4. Copper content in grain ranged from 1.0 mg kg^{-1} in N alone to 3.20 mg kg^{-1} in NPK+CR. Total copper uptake by crop ranged from 4.43 125.07 g ha^{-1} in control to 22.27 g ha^{-1} in NPK+CR. All the fertilizer and manure treatments significantly increased the Cu uptake over control and N alone treatments. Copper uptake was significantly higher in the 100% NPK+CR (22.27 g ha^{-1}) compared to 100% NPK (15.03 g ha^{-1}). Copper uptake by crop increased significantly with increase in level of fertilizer from 11.67 g ha^{-1} in 50% NPK to 15.03 g ha^{-1} with 100% NPK and to 18.37 g ha^{-1} with 150% NPK.

Maheswara Prasad and Prabhu Prasadini (2013) also reported that the incorporation of organic sources (FYM, G*lyricidia* or paddy straw) in the soil along with the NPK fertilizers increased the uptake micronutrients (Zn, Fe, Mn and Cu). Similar results were also reported Rajeev Kumar *et al.* (2000) and Singh *et al.* (1999).

Conclusion

Integrated nutrient management practice by applying FYM or crop residues along with optimum NPK fertilizers (NPK+FYM and NPK+CR) increased the sorghum grain yield and nutrient uptake significantly over application of only fertilizers (100% NPK). Among the graded levels of NPK, sorghum yield increased only up to 100% NPK. Super optimal dose of fertilizers (150% NPK) did not increase the yield. Balanced nutrition (NP/NPK) proved better than imbalanced (only N) application. Imbalanced application of only nitrogen resulted in reduced yields due to the imbalanced use of fertilizers. Additional application of phosphorus significantly increased the yield while there was no significant yield increase with application of potassium, sulphur, boron or zinc. Application of phosphorus, potassium and zinc significantly increased their uptake by the crop but application of nitrogen or sulphur did not increase their uptake.

From the study, it can be concluded that integrated use of organic manure and optimum doses of inorganic fertilizers is necessary for sustained high productivity of the sorghum-sunflower cropping system. It also maintains the soil environment healthy resulting in higher efficiency of applied nutrients as compared to use of inorganic fertilizers alone.

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