Journal of Cereal Research
Volume 14 (Spl - 2): 43-48
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR

Short Communication

Effect of nutrients omission on yield, nutrient uptake and economics of *rabi* sorghum in vertisols under rainfed and irrigated conditions

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Article history: Received: 12 May, 2022 Revised: 20 July, 2022 Accepted: 09 Aug., 2022

Citation: Mohammed Azharuddin BR, Bandiwaddar TT, and Shaila HM. 2022. Effect of nutrients omission on yield, nutrient uptake and economics of *rabi* sorghum in vertisols under rainfed and irrigated conditions. *Journal of Cereal Research* ***14 (Spl-2):*** *43-48. http://doi.org/10.25174/2582-2675/2022/123721*

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Sorghum (*Sorghum bicolor* L. Moench) is one of the important staple food crops for millions of individuals in semi-arid areas. Sorghum is considered as the king of millets and fourth important cereal crop in the country after rice, wheat and maize. It is widely grown in Africa, China and India. In India, sorghum is produced on an area of 4.82 m ha with production of 4.77 mt and a productivity of 1194 Kg ha^{-1} (Anonymus, 2020). Use of high NPK fertilizer, free from micronutrients, limited use of organic manures and restricted recycling of crop residues are some important factors, which have contributed towards accelerated exhaustion of secondary and micronutrients from soil. Nutrient limitations in soils have prompted an intense decrease in yield on a large number of the farms. This is caused by declining soil fertility, which inevitably leads to low agricultural productivity status (Bindraban *et al.*, 2015).

To meet out the uptake of nutrient by crop, soil reserves alone is not adequate and it is important to supply required nutrients through external sources. The nutrient omission plot technique is a tool for determining the measure of fertilizer (N, P and K) needed for attaining a targeted yield. The nutrient omission experiment on *rabi* sorghum might help in arriving at optimum fertilizer recommendations and improve the productivity, nutrient use efficiency and sustainability. Hence, the present investigation is carried out with an objective to assess the impact of nutrients omission on growth and productivity of *rabi* sorghum.

A field experiment was conducted to study the effect of nutrients omission on yield, nutrient uptake and economics of *rabi* sorghum during *rabi* 2020-2021 on clay loam soil under All-India Coordinated Research Project on sorghum, at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad (15^0 29' N, 74^0 59' E 689m altitude). The experiment was laid out in split plot design with three replications. The experiment consists of two main plots *viz.*, Rainfed (M_1) and Irrigated (M_2) and nine sub plots viz.,S_1 - No Omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 kg ha^{-1}),S_2 - FYM Omission (50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1}), S_3 - N omission (25 Kg P_2O_5 ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1}), S_4 - P omission (50 Kg N ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1}), S_5 - Zn omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1}), S_6 - NP omission ($ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1}), S_{7-} N, Zn Omission (25 Kg P_2O_5 + FYM @ 3 t ha^{-1}), S_8 - P, Zn Omission (50 Kg

N ha^{-1} + FYM @ 3 t ha^{-1}) and S_9– Control(N, P, K, Zn and FYM Omission). The field was prepared and line sowing was carried out. *Rabi* sorghum variety CSV – 29 R was sown using 7.5 Kg ha^{-1}seeds on November 18th, 2020 with a spacing of 45cm x 15cm. Nitrogen, phosphorus and zinc were applied in the form of urea, single super phosphate and $ZnSO_4$, respectively, at the time of sowing. Common irrigation was given to both the main plots (M_1 and M_2) immediately after sowing to ensure the proper germination and establishment of the crop. Irrigations were given only for M_2 at booting, flowering and milky stage. The observations (yield, nutrient and economics) recorded were subjected to statistical analysis as described by Gomez and Gomez (1984).

Results indicated that significantly higher grain yield (44.87 q ha^{-1}), stover yield (8.52 t ha^{-1}), total nutrient uptake (93.86 Kg N ha^{-1}, 28.51 Kg P_2O_5 ha^{-1} , 94.04 Kg K_2O ha^{-1}, and 226.24 g Zn ha^{-1}) were recorded under irrigated condition as compared to rainfed condition (Table 1 and 2). The increase in grain yield, stover yield and total nutrient uptake might be due to favourable moisture condition, which helped for better translocation of photosynthates and nutrients resulting in better growth and development. Similar findings were also repoted by Anilkumar *et al.* (2017) that soil application of recommended dose of fertilizer (RDF) along with enriched FYM gave higher grain yield (4.287 t ha^{-1}) and fodder yield (7.51 t ha^{-1}) of *rabi* sorghum. Among the nutrient omissions, application of 50:25 kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} (S_1) recorded significanlty higher grain yield (4.956 t ha^{-1}) and stover yield (9.55 t ha^{-1}). The per cent reduction in grain and stover yield was to an extent of 26.7% and 28.5% respectively, due to omission of nitrogen. While,the per cent reduction in grain and stover yield was to the tune of 31.9 and 34.9 respectively, due to omission of both nitrogen and phosphorous. These results are associated with the findings of Joshi *et al.* (2016) that omission of nutrients such as N, P, K and Zn showed significant effects on grain yield.However, omission of Zn did not affect much on grain and stover yield.

The application of 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} (S_1) recorded significanlty higher total nutrient uptake (109.97 Kg N ha^{-1}, 32.63 Kg P_2O_5 ha^{-1}, 109.33 Kg K_2O ha^{-1} and 283.63 g Zn ha^{-1}). Higher nutrient uptake is due to higher content of nitrogen, phosphorus, potassium and zinc and total dry matter production and its accumulation in grain. These results are supported by findings of Sujathamma *et al.* (2014) that application of 100 per cent RDF recorded the highest N, P, K uptake both by grain and stover. While, omission of NP caused the lowest uptake of total N (69.05 Kg ha^{-1}), total P (21.07 Kg ha^{-1}) and total Zn (215.50 g ha^{-1}). This might be due to the synergetic and antogonistic effects among nutrients. Omission of P and other nutrients reduces the absorption of N because of imbalance in the nutrient supply. Omission of N reduces the phosphorus content in crop (Singh, 2016). These results are supported with the findings of Kumar *et al.* (2018) that omission of N and P reduced the nutrient uptake because nitrogen and phosphorus are the most yield limiting nutrient, which resulted in lower yields and lower uptake of nutrients. The lowest uptake of nutrients were recorded in N omitted plots due to less production of yields. Among the interactions, application of 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} along with irrigation (M_2S_1) recorded significantly higher grain yield (5.473 t ha^{-1}), higher stover yield (10.80 t ha^{-1}) (Table 1), higher total nutrient uptake (119.31 KgN ha^{-1}, 36.49 KgP_2O_5 ha^{-1}, 122.80 Kg K_2O ha^{-1} and 287.22 g Zn ha^{-1}) as given in Table 2. The higher yield might be due to better photosynthates and translocation of nutrients. These results are in line with the findings of Atnafu *et al.* (2021) that maize grain yield obtained was highest for application of NPK and the lowest recorded in N omitted treatment followed by control. The grain yield levels obtained for different fertilizer treatments were ranked as NPK >NPK+ >NP >PK >NK illustrating N deficincy as the most yield limiting nutrient followed by P and K in order. Significantly higher gross returns (₹ 115786 ha^{-1}), net returns (₹ 77085) and BC ratio (2.99) were recorded under irrigated condition compared to rainfed condition (Table 3). Among the nutrient omissions, application of 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} (S_1) recorded significanlty higher gross returns (₹ 128146). While, application of 50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} (S_2) recorded significanlty higher net returns (₹ 88057) and BC ratio (3.41) compared to other nutrient omission treatments. Among interaction effects, application of 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} with irrigation (M_2S_1) recorded significanlty higher gross returns (₹ 142013). While, application of 50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} (M_2S_2) recorded significanlty higher net returns (₹ 101540) and BC ratio (3.77). The improvement in economic returns was mainly due to higher grain and stover yields. The results are in line with findings of Singh (2016) that nitrogen and phosphorus were proved to be the most limiting nutrient in crop production. Thus the development of genotypes with high nutrient use efficiency can be achieved as has also been reported in wheat (Kumar *et al.,* 2019), rice (Zhang *et al.,* 2020) and maize (Atnafu *et al.,* 2021) among other crops.

Table 1: Effect of nutrient omission on grain yield and stover yield of *rabi* sorghum under rainfed and irrigated conditions

Treatments	**Irrigation [No irrigation (M_1) and Irrigated (M_2)]**					
Nutrient Management	**Grain yield (q ha^{-1})**			**Stover yield (t ha^{-1})**		
	M1	**M2**	**Mean**	**M1**	**M2**	**Mean**
S_1 - No Omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1}) [RPP]	44.38	54.73	49.56	8.30	10.80	9.55
S_2 - FYM Omission (50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 kg ha^{-1})	43.02	53.10	48.06	8.10	10.63	9.37
S_3 - N omission (25 Kg P_2O_5 ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	32.67	40.03	36.35	5.90	7.77	6.83
S_4 - P omission (50 Kg N ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	38.67	48.20	43.43	6.73	8.33	7.53
S_5 - Zn omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1})	40.57	50.65	45.61	7.47	9.80	8.63
S_6 - NP omission ($ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	30.22	37.30	33.76	5.57	6.87	6.22
S_7- N, Zn Omission (25 Kg P_2O_5 + FYM @ 3 t ha^{-1})	32.40	39.76	36.08	5.33	7.33	6.33
S_8 - P, Zn Omission (50 Kg N ha^{-1} + FYM @ 3 t ha^{-1})	36.21	44.66	40.44	6.53	8.60	7.57
S_9 – Control (N, P, K and Zn Omission)	29.13	35.40	32.27	5.03	6.53	5.78
Mean	36.36	44.87		6.55	8.52	
	S.Em±		CD at 5%	S.Em±		CD at 5%
Irrigation (I)	0.69		4.24	0.07		0.44
Nutrient (N)	1.01		2.91	0.19		0.55
Interaction (I x N)	1.43		4.12	0.27		0.78

Recommended package of practice 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + ZnSO4 @ 15 Kg ha^{-1} (RPP); M1 – Rainfed condition (No irrigation), M2 – Irrigated Condition

Based on the experimental results, it could be concluded that application of 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} along with protective irrigation at booting, flowering and milky stage significanlty recorded higher grain yield, stover yield, total nutrient uptake, higher protein content, higher gross returns, net returns and BC ratio of *rabi* sorghum. Nitrogen and phosphorus are the most limiting factors to enchance the grain yield, stover yield and for total nutrient uptake. Further, omission of either nitrogen or phosphorus showed a greater reduction in economic returns.

Acknowledgements

Authors thank Principal Scientist – AICRP on Sorghum, MARS, Dharwad for constant encouragements and support.

Compliance with ethical standards: NA

Conflict of interest: No

Author's contribution

Conceptualization of research (MABR); Designing of the experiments (MABR, BTT); Contribution of

Table 2: Effect of nutrient omission on total nutrient uptake of *rabi* sorghum under rainfed and irrigated conditions

Treatments	Irrigation [No irrigation (M_1) and Irrigated (M_2)]											
Nutrient Management	Nitrogen (Kg ha^{-1})			Phosphorus (Kg ha^{-1})			Potassium (Kg ha^{-1})			Zinc (g ha^{-1})		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1 - No Omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1}) [RPP]	100.64	119.31	109.97	28.76	36.49	32.63	95.87	122.80	109.33	280.05	287.22	283.63
S_2 - FYM Omission (50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1})	97.59	116.08	106.84	27.45	35.02	31.24	91.17	117.47	104.32	253.28	260.92	257.10
S_3 - N omission (25 Kg P_2O_5 ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	70.03	82.19	76.11	20.05	25.47	22.76	64.63	83.23	73.93	222.77	230.62	226.70
S_4 - P omission (50 Kg N ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	84.77	99.73	92.25	23.35	29.02	26.19	76.27	94.63	85.45	232.74	240.19	236.47
S_5 - Zn omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1})	90.74	109.43	100.08	25.92	33.17	29.55	83.30	107.77	95.53	203.81	210.92	207.36
S_6 - NP omission ($ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	64.16	73.94	69.05	18.88	23.26	21.07	61.20	75.50	68.35	212.17	218.83	215.50
$S_{7.}$ N, Zn Omission (25 Kg P_2O_5 + FYM @ 3 t ha^{-1})	66.59	79.92	73.26	19.24	24.89	22.07	60.63	80.33	70.48	182.71	187.20	184.96
S_8 - P, Zn Omission (50 Kg N ha^{-1} + FYM @ 3 t ha^{-1})	81.16	96.39	88.77	22.36	28.6	25.46	73.73	94.97	84.35	210.85	217.86	214.35
S_9 - Control(N, P, K and Zn Omission)	58.53	67.74	63.14	16.51	20.75	18.63	54.93	69.67	62.30	176.84	182.40	179.62
Mean	79.36	93.86		22.50	28.51		73.53	94.04		219.47	226.24	
For comparing means	S.Em ± CD at 5%			S.Em ± CD at 5%			S.Em ± CD at 5%			S.Em ± CD at 5%		
Irrigation (I)	1.33	8.11		0.35 2.17			1.04	6.32		0.08 0.49		
Nutrient (N)	2.22 6.39			0.67 1.94			2.23 6.44			0.51 1.48		
Interaction (I x N)	3.14	9.04		0.9 2.75			3.16 9.12			0.72 2.10		

Recommended package of practice 50:25 Kg NP ha-1 + FYM @ 3 t ha-1 + ZnSO4 @ 15 kg ha-1 (RPP); M1 – Rainfed condition (No irrigation) , M2 – Irrigated Condition

Table 3: Effect of nutrient omission on economics of *rabi* sorghum under rainfed and irrigated conditions

Treatments	Irrigation [No irrigation (M_1) and Irrigated (M_2)]											
Nutrient Management	Cost of cultivation (Rs)			Gross Returns (Rs)			Net returns (Rs)			B:C ratio		
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
S_1 - No Omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1}) [RPP]	40726	41046	40886	114280	142013.33	128146.67	73554	100967.3	87260.67	2.80	3.46	3.13
S_2 - FYM Omission (50:25 Kg NP ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1})	36226	36546	36386	110800	138086.67	124443.33	74574	101540.6	88057.33	3.05	3.77	3.41
S_3 - N omission (25 Kg P_2O_5 ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	40187	40507	40347	83666.67	103920.00	93793.33	43479.67	63413	53446.33	2.08	2.56	2.32
S_4 - P omission (50 Kg N ha^{-1} + $ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	39214	39534	39374	98533.33	122706.67	110620	59319.33	83172.67	71246.00	2.51	3.10	2.80
S_5 - Zn omission (50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1})	39751	40071	39911	104180	130993.33	117586.67	64429.00	90922.33	77675.67	2.61	3.27	2.94
S_6 - NP omission ($ZnSO_4$ @ 15 Kg ha^{-1} + FYM @ 3 t ha^{-1})	38675	38995	38835	77646.67	95793.33	86720	38971.67	56798.33	47885.00	2.01	2.45	2.23
S_{7-} N, Zn Omission (25 Kg P_2O_5 + FYM @ 3 t ha^{-1})	39212	39532	39372	81946.67	102153.33	92050	42734.67	62621.33	52678.00	2.08	2.58	2.33
S_8 - P, Zn Omission (50 Kg N ha^{-1} + FYM @ 3 t ha^{-1})	38239	38559	38399	92706.67	115466.67	104086.67	54467.67	76907.67	65687.67	2.42	2.99	2.71
S_9 – Control (N, P, K and Zn Omission)	33200	33520	33360	74233.33	90946.67	82590	41033.33	57426.67	49230.00	2.23	2.71	2.47
Mean	38381	38701		93110.37	115786.67		54729.26	77085.56		2.42	2.99	
For comparing means				S.Em ± CD at 5%			S.Em ± CD at 5%			S.Em ± CD at5%		
Irrigation (I)				1700.1110344.97			1700.114 10344.97			0.042 0.25		
Nutrient (N)				2551.83 7350.95			2551.83 7350.95			0.067 0.19		
Interaction (I x N)				3608.83 10395.81			3608.833 10395.81			0.095 0.27		

Recommended package of practice 50:25 Kg NP ha^{-1} + FYM @ 3 t ha^{-1} + ZnSO4 @ 15 Kg ha^{-1} (RPP); M1 – Rainfed condition (No irrigation), M2 – Irrigated Condition experimental materials (MABR, BTT); Execution of field/lab experiments and data collection (MABR, BTT); Analysis of data and interpretation (MABR, BTT, SHM); Preparation of the manuscript (MABR, BTT).

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