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Estimation of Nutrient Uptake and Available Nutrient Status of *Rabi* Safflower Through Soil Test Crop Response in *Rainfed* Ecosystem

S.D. Hiwale[1], A.B. Chorey[2], S.S. Patil[3]

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ABSTRACT

Background: Adoption of SSNM is directly affected by cost of fertilizer. Soil test crop response (STCR) concept attribute to contribution of soil and targeted yield level for fertilizer recommendation for a selected crop. This approach is also known as prescription based fertilizer recommendations. It is specific type of soil, climatic condition and specific location. Nutrient requirement is differ for different crops. The available soil nutrients efficient used and added to those available soil nutrients through fertilizers is different for different type of soil geography under a particular set of climatic conditions.

Methods: A research experiment was carried out during *rabi* 2017-18, 2018-19 and 2019-20 at Research Farm of Agronomy, Dr. P.D.K.V, Akola (Maharashtra). Fertilizers were applied based on uptake pattern of crop, target yield levels and soil test values. The experiment was laid out in FRBD-Factorial randomized block design with two factors. Total 15 treatment combinations were formed which replication 4 times.

Result: Significantly greater uptake of nitrogen (62.76, 74.67 and 81.89 kg ha^{-1}), phosphorus (19.15, 24.32 and 29.38 kg ha^{-1}), potassium (80.32, 92.14 and 99.18 kg ha^{-1}), sulphur (18.46, 24.10 and 26.03 kg ha^{-1}) and zinc (493.97, 571.01 and 620.91 g ha^{-1}) recorded in treatment where crop supplied with farm yard manure @ 5 t ha^{-1} than rest of treatments during 2017-18, 2018-19 and 2019-20, respectively. A similar trend was observed in respect of soil nutrient status such as available N, P_2O_5, K_2O, S and Zn. Application of fertilizers through soil test crop response equation with zinc sulphate @ 25 kg ha^{-1} and Sulphur @ 10 kg ha^{-1} registered maximum total uptake of nitrogen (66.89, 78.99 and 90.06 kg ha^{-1}), phosphorus (20.78, 25.31 and 31.96 kg ha^{-1}), potassium (86.05, 97.99 and 109.09 kg ha^{-1}), sulphur (20.27, 26.39 and 29.80 kg ha^{-1}) and zinc (537.78, 618.06 and 696.21 g ha^{-1}) than rest of nutrient management treatments during three years of field experiment, respectively. The same trend was observed with respect to available N, P_2O_5, K_2O, S and Zn under respective treatment during three years of experimentation.

Key words: Climate action, Food, Life on land, Nutrient uptake, Organic manures, *Rabi* safflower, *Rainfed,* Responsible consumption and production, SSNM, STCR, Zero hunger.

INTRODUCTION

Carthamus tinctorius Linn placed in Compositae or Asteraceae family and originated from Abyssinia and Afganisthan. It is locally known as *Kardai, Kusumbha* and *Kusum*. Safflower is mainly grown for the edible oil (24-36%) by Singh *et al.* (2020). Since it is dying oil, it has industrial uses in the manufacture of paints, varnishes, soap making, waterproofing material and plastic adhesives for glass. Singh *et al.* (2020) observed that the oil cake from decorticated seed is fed to cattle and it contains 40-50% protein. The oil contains more polyunsaturated fatty acids like lineolic and linolic and it is good for heart patient as it maintains low level of blood cholesterol. As the natural color is obtained from carthamine pigment and the petals having medicinal value, cure rheumatism. The ray and disc florets can be used as the substitute for saffron. The roasted seeds can be eaten or seeds are very relishable food to pigeons. The hull or seed coat used for the preparation of hard board, fuel or decoration. It acts as guard crop as it protects main crop against stray cattle. Safflower oilseed cake contains 5% N, 1.44% P_2O_5, 1.23 K_2O% which is used as source of organic manure Singh *et al.* (2020).

[1]Department of Agronomy, Dr. Panjabrao Deshmukh krishi Vidyapeeth, Akola-444 104, Maharashtra, India.
[2]All India Coordinated Research Project for Dry land Agriculture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola-444 104, Maharashtra, India.
[3]Department of Agronomy, Lovely Professional University, Phagwara-144 411, Punjab, India.
[#]All authors contributed equally to this work.

Corresponding Author: S.S. Patil, Department of Agronomy, Lovely Professional University, Phagwara-144 411, Punjab, India. Email: sushant.26367@lpu.co.in

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Triptesh *et al.* (2016) observed that SSNM is one of the scientific approaches to supply the nutrients that match field specific or site specific nutrient requirement of crop.

Recommendation with blanket application of nutrients or fertilizers promoted over application of fertilizers in some area of field and under application of fertilizer in other area of field which leads to imbalanced application of nutrient management. SSNM is an best alternative to blanket fertilizer applications recommendation. Site Specific nutrient management is utilizing various tools modern Agriculture technology such remote sensing, geographic information system, global positioning system, variable rate technology, *etc* to optimize the supply of essential nutrient over space and time to meet nutrient requirement of crop through 4R's of nutrient management *i.e* right product, right rate, right time, right place. SSNM help to increase productivity by enhancing or fertilizer or nutrient use efficiency and profitability by reducing excess cost on fertilizer. It mitigates release of green house gases from agriculture due to excess nitrogen application for crop production.

MATERIALS AND METHODS

A research experiment was carried out during *rabi* 2017-18, 2018-19 and 2019-20 at research farm of agronomy, Dr. P.D.K.V, Akola (Maharashtra). Experiment was conducted on medium deep black soil. Initial nutrient status of soil indicted 194.0 kg ha^{-1} of available nitrogen 26.10 kg ha^{-1} of available phosphorus and slightly high in 327.00 kg ha^{-1} of available potassium. Chemical analysis soil indicated that pH=8.0, electrical conductivity=0.30 dSm^{-1} and Organic carbon=0.59. Fertilizers were applied based on uptake pattern of crop, target yield levels and soil test values. The experiment was laid out in FRBD-factorial randomized block design with two factors. Total 15 treatment combinations were formed which replication 4 times. Treatments were applied to safflower crop as shown in Table 1.

The AKS-207 variety of safflower was sown on 6th Oct 2017, 24th Sept 2018 and 27th Sept 2019, respectively. Safflower seeds were dibbled at 45 cm × 20 cm spacing. Gross plot size of research experiment 5.4 m × 4 m and 4.5 m × 3.6 m net executed during the experimental years. Farm yard manure @ 5 t ha^{-1} and green gram residue (wet basis) @ 2 t ha^{-1} were incorporated to the field before the sowing of safflower. Nutrient were added to the soil through diffrent sources as per the treatments shown in Table 2. Total rainfall during sowing to harvest of safflower were 66.10 mm in 06 rainy days, 175.3 mm in 06 rainy days and 193.1 mm in 14 rainy days during was 2017-18, 2018-19 and 2019-20, respectively. FYM contains 0.46 % N, 0.17% P_2O_5, 0.48% K_2O and green gram residue contains 1.61% N, 0.22% P_2O_5, 0.55% K_2O.

Soil test crop response equation

STCR equation of safflower crop for targeted yield used for present study has been developed by JNKV-Jawaharlal

Table 1: Treatment details.

Sr. no.	Treatments
A.	**Manure sources**
M0	No manure
M1	5 t FYM ha^{-1}
M2	Green gram (Residue incorporation)
B.	**Nutrient management**
F0	Control (No fertilizer)
F1	Recommended NPK
F2	Site Specific Nutrient Management (Soil Test Crop Response equation)
F3	SSNM (STCR equation) + ($ZnSo_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})
F4	SSNM NPK (deficient: +25% recommended; Medium: recommended; high:-25% recommended)

Table 2: Nutrients applied in safflower under different treatments.

Treatment	Nutrient supplied through different sources (kg ha^{-1})				
	N	P_2O_5	K_2O	S	Zn
No manure	0.00	0.00	0.00	-	-
Green gram residue incorporation	20.93	2.86	7.15	-	-
Control (No fertilizer)	00	00	00	-	-
Recommended NPK	40	25	00	-	-
SSNM (STCR equation)	49.35	36.90	14.79	-	-
SSNM (STCR equation) + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	49.35	36.90	14.79	10	25
SSNM NPK (deficient + 25% rec.; Medium: rec.; high: -25% rec)	50	31.25	00	-	-

Table 3: Nitrogen (kg ha^{-1}) and phosphorus (kg ha^{-1}) potassium (kg ha^{-1}), sulphur (kg ha^{-1}) and zinc uptake (g ha^{-1}) as influenced by different treatments during 2017-2018, 2018-2019 and 2019-2020.

Treatments	2017 -2018	2018 -2019	2019 -2020	2017 -2018	2018 -2019	2019 -2020	2017 -2018	2018 -2019	2019 -2020	2017 -2018	2018 -2019	2019 -2020	2017 -2018	2018 -2019	2019 -2020
	N uptake (kg ha^{-1})	N uptake (kg ha^{-1})	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	P uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	K uptake (kg ha^{-1})	K uptake (kg ha^{-1})	S uptake (kg ha^{-1})	S uptake (kg ha^{-1})	S uptake (kg ha^{-1})	Zn uptake (g ha^{-1})	Zn uptake (g ha^{-1})	Zn uptake (g ha^{-1})
A) Manure sources															
M_0: No manure	47.33	52.60	57.08	13.15	15.55	18.55	61.60	68.87	71.75	12.47	15.13	16.12	346.10	390.45	418.24
M_1: 5 t FYM ha^{-1}	62.76	74.67	81.89	19.15	24.32	29.38	80.32	92.14	99.18	18.46	24.10	26.09	493.97	571.01	620.91
M_2: Greengram (residue incorporation)	57.40	66.49	76.60	17.15	20.59	26.24	76.01	82.99	95.52	16.43	20.65	23.98	449.73	497.08	568.76
SE m±	1.87	2.65	3.14	0.85	1.53	1.89	3.92	3.83	3.80	0.85	1.63	1.98	15.85	22.27	27.34
CD @ 5%	5.35	7.55	8.97	2.43	4.38	5.40	11.19	10.94	10.85	2.44	4.64	5.65	45.25	63.57	78.02
B) Nutrient management															
F_0: Control (No fertilizer)	42.62	46.52	52.12	11.48	13.42	16.60	55.38	59.40	66.77	10.34	11.71	13.23	298.80	322.35	369.89
F_1: Recommended NPK	53.35	59.67	66.39	15.49	18.73	22.89	70.19	74.87	80.97	14.54	17.26	18.66	401.01	433.94	473.28
F_2: SSNM (STCR equation)	60.87	70.81	79.01	18.52	22.46	28.07	79.55	89.62	97.35	17.47	22.86	25.73	485.84	553.61	608.21
F_3: F_2 + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	66.89	78.99	90.06	20.78	25.31	31.96	86.05	97.99	109.09	20.27	26.39	29.80	537.78	618.06	696.21
F_4: SSNM (NPK) (deficient: +25% rec, medium: rec, high: - 25%)	55.43	66.95	71.68	16.14	20.84	24.09	72.05	84.79	89.91	16.29	21.56	22.90	426.24	502.92	532.27
SE m±	2.42	3.42	4.06	1.10	1.98	2.44	5.06	4.95	4.91	1.10	2.10	2.56	20.47	28.76	35.29
CD @ 5%	6.91	9.75	11.58	3.14	5.65	6.97	14.45	14.12	14.00	3.15	5.99	7.30	58.42	82.07	100.72
Interaction (M × F)															
SE m±	4.19	5.92	7.03	1.91	3.43	4.23	8.77	8.57	8.50	9.91	3.63	4.43	35.45	49.81	61.12
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	55.83	64.59	71.85	16.48	20.15	24.72	72.64	81.33	88.82	15.78	19.96	22.06	429.93	486.18	535.97

Table 4: Available nitrogen (kg ha^{-1}) and available phosphorus (kg ha^{-1}), available potassium (kg ha^{-1}), available sulphur (mg kg^{-1}) and available zinc (mg kg^{-1}) as influenced by different treatments during 2017-2018, 2018-2019 and 2019-2020.

Treatments	2017 -2018 N (kg ha^{-1})	2018 -2019 N (kg ha^{-1})	2019 -2020 N (kg ha^{-1})	2017 -2018 P (kg ha^{-1})	2018 -2019 P (kg ha^{-1})	2019 -2020 P (kg ha^{-1})	2017 -2018 K (kg ha^{-1})	2018 -2019 K (kg ha^{-1})	2019 -2020 K (kg ha^{-1})	2017 -2018 S (mg kg^{-1})	2018 -2019 S (mg kg^{-1})	2019 -2020 S (mg kg^{-1})	2017 -2018 Zn (mg kg^{-1})	2018 -2019 Zn (mg kg^{-1})	2019 -2020 Zn (mg kg^{-1})
A) Manure soureces															
M_0: No manure	192.00	190.55	196.39	22.82	23.00	26.43	326.30	326.80	328.30	7.09	7.03	7.53	0.50	0.51	0.54
M_1: 5 t FYM ha^{-1}	210.95	217.41	222.18	27.81	29.38	31.58	336.75	338.06	342.03	8.73	9.28	10.00	0.57	0.61	0.66
M_2: Greengram (residue incorporation)	206.89	207.15	215.39	23.39	26.71	28.95	332.70	337.10	340.10	7.54	8.16	8.86	0.55	0.57	0.61
SE m±	0.65	1.05	1.58	0.41	0.73	0.80	1.08	1.50	1.62	0.16	0.22	0.25	0.04	0.03	0.04
CD @ 5%	1.84	3.01	4.52	1.16	2.08	2.30	3.08	4.28	4.62	0.46	0.63	0.73	NS	NS	NS
B) Nutrient management															
F_0: Control (No fertilizer)	190.52	188.21	193.63	21.25	22.50	23.34	324.75	325.03	325.97	6.26	6.73	7.42	0.49	0.50	0.50
F_1: Recommended NPK	203.88	215.50	218.24	26.80	28.50	29.38	333.25	334.00	336.08	7.53	7.72	8.42	0.53	0.55	0.59
F_2: SSNM (STCR equation)	212.47	219.40	224.22	28.80	29.96	31.46	336.58	339.08	341.08	8.15	8.75	9.43	0.55	0.59	0.64
F_3: F_2 + ($ZnSO_4$ @ 25 kg ha^{-1} + S @ 10 kg ha^{-1})	216.13	221.95	228.33	30.10	33.13	34.00	340.67	343.33	346.08	9.27	9.46	10.15	0.61	0.63	0.66
F_4: SSNM (NPK) (deficient: +25% rec, medium: rec, high:-25%)	209.03	216.00	221.50	27.90	28.10	30.08	335.33	337.17	339.17	7.71	8.11	8.80	0.54	0.57	0.61
SE m±	0.83	1.36	2.04	0.52	0.94	1.04	1.39	1.93	2.09	0.21	0.29	0.33	0.05	0.04	0.05
CD @ 5%	2.38	3.89	5.84	1.49	2.69	2.96	3.97	5.52	5.96	0.59	0.82	0.94	NS	NS	NS
Interaction (M × F)															
SE m±	1.44	2.36	3.54	0.91	1.63	1.80	2.41	3.35	3.62	0.36	0.50	0.57	0.09	0.07	0.08
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GM	204.61	208.56	215	26.11	27.47	29.40	333.29	335.32	337.35	7.78	8.15	8.84	0.54	0.57	0.60
Initial soil status	194	194	194	26.10	26.10	26.10	327	327	327	8.0	8.0	8.0	0.52	0.52	0.52

Nehru Krishi Vidyapeeth, Jabalpur. Considering the similar type of geography, soil type and climatic condition of Jabalpur, the said equation has been used at Akola for conducting experiment with safflower crop.

Soil test crop response equation

$$F.N = 9.11\ T - 0.45\ S.N$$
$$F.P_2O_5 = 6.27\ T - 2.19\ S.P$$
$$F.K_2O = 9.27\ T - 0.38\ S.K$$
$$\text{Target yield} = 15\ q\ ha^{-1}$$

Where:
F N - Fertilizer N (kg ha^{-1}).
F P_2O_5 - Fertilizer P_2O_5 (kg ha^{-1}).
F K_2O - Fertilizer K_2O (kg ha^{-1}).
T - Target yield (q ha^{-1}).
SN - Soil available N (kg ha^{-1}).
SP - Soil available soil P_2O_5 (kg ha^{-1}).
SK - Soil available soil K_2O (kg ha^{-1}).

RESULTS AND DISCUSSION

Nutrient uptake (kg ha^{-1}) by safflower

Effect of different organic sources

The data in Table 3 indicate that significantly higher uptake of nitrogen (62.76, 74.67 and 81.89 kg ha^{-1}), phosphorus (19.15, 24.32 and 29.38 kg ha^{-1}), potassium (80.32, 92.14 and 99.18 kg ha^{-1}), sulphur (18.46, 24.10 and 26.09 kg ha^{-1}) and zinc uptake (493.97, 571.01 and 620.91 g ha^{-1}) recorded by application of FYM @5 t ha^{-1} (M_1) to soil in safflower, being comparable with treatment where green gram residue buried in soil (M_2), during all the year of experimentation. Except nitrogen uptake during 2019-20 and zinc uptake during 2018-19, 2019-20 and significantly superior over no application of manure treatment during first, second and third year of study. The higher nutrient uptake by crop might be due to improvement in soil health through application of organic manure. The results are also corroborated the findings of Datta and Mondal (2006); Rana and Badiyala (2014); Padmavathi *et al.* (2016) and Krithika *et al.* (2024).

Effect of nutrient management treatments

The data in Table 3 indicated that the highest total uptake of nitrogen (66.89, 78.99 and 90.06 kg ha^{-1}), phosphorus (20.78, 25.31 and 31.96 kg ha^{-1}), potassium (86.05, 97.99,109.09 kg ha^{-1}), sulphur (20.27, 26.39 and 29.80 kg ha^{-1}) and zinc (537.78, 618.06 and 696.21 g ha^{-1}) were obtained with application of fertilizer through STCR with Zinc Sulphate @ 25 kg ha^{-1} and Sulphur @ 10 kg ha^{-1} (F_3), which was significantly superior over rest of nutrient management treatments and was found at par with treatment of STCR (F_2), respectively.

This might be due to the fact that efficient utilization specific nutrients by the healthy and vigorous plants at various vegetative and reproductive growths which were increases nutrient uptake by plant. These results are in consonance with Majumder *et al.* (2017) and Krithika *et al*. (2024).

Available N, P, K, S, Zn status in soil

Effect different organic sources

Data on available nitrogen, phosphorus, potassium, Sulphur and Zinc in soil as influenced by different treatments during 2017-18, 2018-19 and 2019-20 are presented in Table 4. The results revealed that the highest available nitrogen (210.95, 217.41 and 222.18 kg ha^{-1}), phosphorus (27.81, 29.38 and 31.58 kg ha^{-1}), potassium (336.75, 338.06 and 342.03 kg ha^{-1}) and sulphur (8.73, 9.28 and 10.00 mg kg^{-1}), respectively in soil was registered with application of 5 t farm yard manure ha^{-1} (M_1) and superior than other manure application treatments during 3 years of experimentation. There was no significant change in concern with available zinc (mg kg^{-1}) in soil after harvest of safflower during all year of experimentation. FYM application increased the soil organic matter content in soil. Further, they have reported that organic manure had greater residual effect on long term basis. The results are in close agreement with the findings by Rana and Badiyala (2014).

Effect of nutrient management

Data on available nitrogen, phosphorus, potassium, sulphur and zinc in soil as influenced by different treatments during 2017-18, 2018-19 and 2019-20 are presented in Table 4. During 2017-18, 2018-19 and 2019-20, the status of available nitrogen (216.13, 221.95 and 228.33 kg ha^{-1}), phosphorus (30.10, 33.13 and 34.00 kg ha^{-1}), potassium (340.67, 343.33 and 346.06 kg ha^{-1}) and sulphur (9.27, 9.46 and 10.15 mg kg^{-1}) in soil significantly improved with the application of STCR with $ZnSO_4$ @ 25 kg ha^{-1} and S @ 10 kg ha^{-1}) (F_3) as compared to rest of other nutrient management treatments, respectively. There was no significant change in respect to available zinc (mg kg^{-1}) in soil after harvest of safflower during the three year of experiment.

Baskar *et al.* (2017) noticed that balanced application of inorganic fertilizers with organic manure at the time of sowing help to increase growth attributes and yield attributes which reflected in yield of crop. Increased in available NPK with FYM application was also reported by Arbad *et al.* (2012), Subehia and Sepehya (2012) and Basavaraja *et al.* (2019); Abishek *et al.* (2024).

CONCLUSION

Form the nutrient transformation data of three years of experimentation it can be concluded that supply of farm yard manure @ 5 t ha^{-1} is the best practice that con be adopted for safflower crop in respect of nutrient uptake of major and micronutrient, available soil nutrient status and seed yield of safflower. Similarly, for nutrient management point of view, the treatment adopted Site Specific Nutrient Management or Soil Test Crop Response equation+Zinc sulphate @ 25 kg ha^{-1} + Sulphur @ 10 kg ha^{-1} noticed higher uptake of

nitrogen, phosphorus, potassium, sulphur and zinc with beneficial impact on yield of safflower and increased available nutrient soil status. Hence it is suggested that for getting optimum safflower productivity, maximum nutrient use efficiency and environmentally sustainable, balanced amount of fertilizers and integrated nutrient management with organic manures should be adopted.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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