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Response of rainfed soybean [*Glycine max* (L.) Merrill] to nutrient application in vertisols of western part of Nimar

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Abstract
Crop yield data of soybean has been affected significantly due to various fertility treatments. The micronutrient application / FYM application @ 6 t ha^{-1} when applied with RDF gave higher seed and stover yield as compared to RDF without micronutrient application. The RDF was statistically at par with the treatments comprising of RDF + micronutrient. Treatment T_{15} (Control) was found significantly inferior to all the treatments. On the basis of two years pooled data the highest soybean seed and stover yield of 2083.0 and 3033.7kg ha^{-1} was recorded with treatment T_5 (20:60:20 kg NPK ha^{-1} + S_{40}). Seed yield data revealed that treatments comprising of soil application of Mo gave higher seed yield when applied with RDF than seed treatment. Treatment comprising of application of micronutrient along with RDF gave higher B:C ratio than RDF alone. The lowest B:C ratio was obtained in case of treatment T_{15} i.e. control. The treatments which comprises recommended dose of fertilizer addition of S/Zn/Mo along with RDF further increases oil content but this increase was non-significant.

Keywords: Nutrient application, vertisol, soybean, yield, oil content

Introduction
Soybean [*Glycine max* (L.) Merrill] is known as the "Golden Bean" native to East Asia. The origin of soybean is unclear, but many botanists believe it to have earned from *Glycine ussuriensis*, a legume native to central China that has been used for 5000 years as a food and drug components. Soybean is belonging to family leguminoceae, sub-family Papilionaceae and the genus Glycine. It is grouped as an oilseed as well as pulse crop, which has unmatched composition of 40 per cent protein and 20 per cent oil and nutritional superiority on account of containing essential amino acids, unsaturated fatty acids, carbohydrates, vitamins and minerals and 20-30% extractable substance has established its potential as an industrial vital and viable oilseed crop in India (FAO, 1982) [7]. After recovery of oil from soybean seed, the residual meal is soya cake which is called as meat for the poor and consumed in human food. Madhya Pradesh is designated as "Soya State of India" and possess I^{st} rank in its production. It has the potential to bridge the gap between the demand and supply of edible oil and protein. In western part of Nimar the area is 60.2 thousand ha with total production 52.0 thousand q and productivity is 865 kg ha^{-1} (Anonymous, 2019) [2].
As rainfed agriculture becomes increasingly intensive, the nutrient deficiencies in the soil-plant system are also likely to increase. The continuous application of only NPK depleted the zinc to below critical level. Secondary and micronutrients play an important role in increasing yield of oilseed legumes through their effects on the plant itself and on the nitrogen fixing symbiotic process. The deficiency of these nutrients has been very pronounced under multiple cropping systems due to excess removal by HYV of crops and hence their exogenous supplies are urgently required. Hence maximum attention needs with respect to macro and micronutrient nutrition in order to boost the productivity of rainfed soybean. As the meagre information is available on the response of these crops to applied macro and micro nutrient, there is need to study the nutrient status and responses in soybean crop under rainfed Vertisols of western part of Nimar for improving productivity.

Materials and Methods
A field experiment was laid out under rainfed conditions in randomized block design at Instructional farm of RVSKVV-Krishi Vigyan Kendra, Khargone (M.P.) during two consecutive *Kharif* seasons of 2017 and 2018 respectively in Vertisols of West Nimar.

There were fifteen treatments of different fertilizer combinations as well as doses and allocated randomly in three replications. The gross plot size was 5.0 m x 4.0 m and after leaving non-experimental margin on both sides, the net experimental plot size was 4.0 m x 3.2 m. Soybean [*Glycine max* (L.) Merrill] crop (cv. JS-9305) was sown manually with spacing of 45 x 5 cm on July and harvested on October in both the years (2017 and 2018) respectively. The details of different treatments were laid out during the investigation as follows.

Treatment No.		Treatment Detail
T_1	:	Recommended dose of NPK (20:60:20 kg NPK ha^{-1})
T_2	:	Recommended dose of NP (20:60:0 kg NPK ha^{-1})
T_3	:	Recommended dose of N (20:0:0 NPK ha^{-1})
T_4	:	T_1 (20:60:20 kg NPK ha^{-1}) + S_{20} (Sulphur 20 kg ha^{-1})
T_5	:	T_1 (20:60:20 kg NPK ha^{-1}) + S_{40} (Sulphur 40 kg ha^{-1})
T_6	:	T_1 (20:60:20 kg NPK ha^{-1}) + Mo @ 0.5 kg ha^{-1}(Soil Application)
T_7	:	T_1 (20:60:20 kg NPK ha^{-1}) + Mo @ 1 g kg^{-1} seed (Seed Treatment)
T_8	:	T_3 (20:0:0 NPK ha^{-1}) + Mo @ 0.5 kg ha^{-1} (Soil Application)
T_9	:	T_3 (20:0:0 NPK ha^{-1}) + Mo @ 1 g kg^{-1} seed (Seed Treatment)
T_{10}	:	T_1 (20:60:20 kg NPK ha^{-1}) + Zn (Soil application) @ 25 kg $ZnSo_4$ ha^{-1}
T_{11}	:	T_2 (20:60:0 kg NPK ha^{-1}) + Zn (Soil application) @ 25 kg $ZnSo_4$ ha^{-1}
T_{12}	:	T_3 (20:0:0 NPK ha^{-1}) + Zn (Soil application) @ 25 kg $ZnSo_4$ ha^{-1}
T_{13}	:	50% RDF (10:30:10 kg NPK ha^{-1}) + 6 t ha^{-1} FYM
T_{14}	:	Farmer's practice (DAP 125 kg ha^{-1})
T_{15}	:	Control (No fertilizer)

All the required nutrients were applied manually as basal dose as per the requirement of the treatment. Seed treatment of soybean with Mo was done @ 1 g Ammonium Molybdate per kg seed at the time of sowing as per the treatment required. Insect pest control measures were adopted as per the requirement. Analytical techniques and observations on the growth attributory characters were taken from each treatment by selecting five representative plants randomly and the mean values were presented. The plant height (cm), no. of branches $plant^{-1}$, Pods $plant^{-1}$, Seed pod^{-1}, 100 seed wt. (g) were measured. Which were adopted for the present studies, are: Growth attributory characters, Seed & Stover yield, and Harvest index.

Results and Discussion

Effect of nutrient application on Growth Parameters and Yield of Soybean crop

The data pertaining to the growth and yield attributing characters are presented in Table 1. It is evident from the data that the crop growth parameters and yield attributing characters were significantly influenced by the various nutrients application treatments. Pooled analysis of two years data emphasized that the treatment T_{10} - 20:60:20 kg NPK ha^{-1} + Zn @ 5 kg ha^{-1} (25 kg $ZnSo_4$ ha^{-1}) recorded the highest plant height (44.27 cm) followed by the treatments T_5 (43.65 cm), T_4 (43.01 cm), T_6 (42.40 cm), T_7 (41.86 cm), T_{13} (41. 58 cm), T_1 (41.12 cm), T_{11} (40.35 cm) all these treatments were at par with each other. The lowest plant height was recorded in case of treatment T_{15} i.e. Control (No fertilizer application) which was found statistically inferior to all the treatments except T_2, T_3, T_8, T_9, T_{12} and T_{14}.

Overall results suggest that plant height has been influenced significantly by nutrient application. RDF and application of M/Zn along with recommended level of N has given significantly higher plant height. Similarly, 50% of RDF along with 6 t ha^{-1} FYM was also found equally effective as that of RDF. Almost similar trend was also observed in case of number of branches $plant^{-1}$. Pooled analysis revealed that the highest pods $plant^{-1}$ (53.30) was recorded in case of T_5-20:60:20 kg NPK ha^{-1} + S_{40} which was found at par with treatments T_4, T_6 and T_{10}. The lowest pods per plant were recorded in case of T_{15}: Control treatment where no fertilizer was applied. This treatment was found statistically inferior to T_4, T_5, T_6, and T_{10} treatments. Rest of the treatments were at par with T_{15}. This trend was also maintained in case of seed pod^{-1} and test weight also. The highest seed yield was recorded in T_5 and lowest in T_{15}. T_{15} was found statistically inferior to rest of the treatments, while the treatments T_4, T_6, T_7 and T_{10} were found statistically at par with each other. The overall results emphasized that recommended dose of N, P, K along with either S, Mo, Zn enhances crop productivity. If we apply FYM @ 6 t ha^{-1} one can reduce use of chemical fertilizer up to 50% of RDF without sacrificing the seed yield. Sub optimal doses of RDF significantly reduces the seed yield significantly. Similar findings were also reported by many workers. The results in conformity with the findings of Ramesh *et al.*, (2008) [13], Thenua *et al.*, (2010) [18], Kumawat *et al.*, (2010) [11] and Devi *et al.*, (2014) [6]. The higher yield was due to better supply of metabolites and photosynthesis. In addition to supply of organic manures with 50% inorganic fertilizers improved the yield attributes resulting enhanced the yield of soybean. The Stover yield of soybean crop as influenced by various treatments was recorded and data presented in Table 1. The maximum and minimum Stover yield 3033 and 1807 kg ha^{-1} recorded on pooled basis. During study highest Stover yield was recorded in case of T_5-20:60:20 kg NPK ha^{-1} + S_{40} and lowest in case of T_{15} Control i.e. where we did not apply any fertilizer. Treatments T_4, T_6, T_7, T_{10} and T_{13} were at par with each other. The treatment T_{15} found statistically inferior to the rest of the treatments under study. Harvest index (%) ranged from 37.8 to 42.8 on pooled basis under study. The effect of various treatments were non-significant on the harvest index of soybean crop. The lowest harvest index was found in case of T_{15} Control treatment. Results of a field experiment conducted on a Zn deficient calcareous silt loam showed that, it was 10 kg Zn ha^{-1} application that led to maximum response from recommended dose of NPK (Sakal *et al.* 1988) [16]. A single application of 5 to 10 kg Zn ha^{-1} leaves residual effect, which is seen to last for 2 to 5 years. Longevity of residual benefits depends primarily on the initial rate of application; higher rate produce long lasting benefits (Takkar *et al.*, 1997) [17]. Influence of micronutrients in optimum use of macronutrients is rooted in the fact that if supply of the farmer falls short of that needed

for optimum crop growth and yield, response to latter will be impaired in economic and environmental terms. Many studies have proves this association (Katyal and Agarwal, 1982, Katyal 1985, Takkar *et al*., 1997 and Rattan *et al*., 1999) [17, 9, 8, 15]. Studies conducted under rainfed condition have indicated a good response to zinc and molybdenum application. Nevertheless, the studies conducted at AICRP on dryland Agriculture Banglore (2003) revealed that combined foliar spray of $ZnSo_4$ @ 2.5 kg ha^{-1} + Borax @ 0.5 kg ha^{-1} recorded significantly higher pod (1202 kg ha^{-1}) yield with 32% increase in groundnut yield over control.

Effect of Nutrient application on Oil content, Oil Yield and Protein content of soybean Crop

The oil content (%) and oil yield (kg ha^{-1}) of soybean crop was also influenced by various treatments and data presented in Table 2. The data presents in table showed that the oil content and oil yield of soybean is significantly affected by nutrient application. The treatments which comprises recommended dose of fertilizer addition of S/Zn/Mo along with RDF further increases oil content but this increase was non-significant. Sub optimal doses of fertilizer reduces oil content significantly in soybean crop as compared to other treatments under study. It is also quite evident from the data that the application of 6 t ha^{-1} along with 50% of RDF gave at par oil content to 100% RDF and RDF + S/Zn/Mo. Thus by the addition of organics we can reduce the use of chemical fertilizer up to 50% without affecting soybean oil content significantly. Even if we apply recommended dose of nitrogen only along with Mo/Zn helps to sustain oil content in soybean crop as these treatments were found statistically at par with the treatments which comprised of 100% RDF. The oil content in treatment T_4 and T_5 were found at par so it seems in these soils if we apply 20 kg S along with RDF is sufficient to sustain oil content in soybean crop. These trends also existed in the pooled analysis of two years data. The oil yield data revealed that the oil yield significantly influenced by the nutrient management. It ranged from 395 to 179 kg ha^{-1} based on pooled analysis. The highest oil yield 395 kg ha^{-1} was recorded in treatment T_5 20:60:20 kg NPK ha^{-1} + S_{40} followed by 392 kg ha^{-1} (T_4), 379 kg ha^{-1} (T_{10}), 368 kg ha^{-1} (T_6), 354 kg ha^{-1} (T_7), 350 kg ha^{-1} (T_{13}), 334 kg ha^{-1} (T_{11}) and 337 kg ha^{-1} (T_1). All these treatments were statistically at par with each other. The lowest 179 kg ha^{-1} oil yield was observed in T_{15} treatment where no fertilizer was applied. This treatment was found statistically inferior to rest of the treatments. Treatments T_2, T_3, T_7, T_8, T_9, T_{12} and T_{14} were found at par with each other but were significantly superior to T_{15} control and inferior to T_4, T_{10}, T_6, T_7, T_{13}, T_{11} and T_1.

Protein content was also affected by nutrient management treatments and data presented in Table 2. It is evident from the data that the protein content was influenced significantly by various treatments. The highest protein content (36.83%) was found in the treatment T_7 which was found at par with the 36.31% (T_6), 35.06% (T_8), 35.15% (T_{13}), 34.96% (T_{11}), 34.77% (T_{10}), 34.56% (T_5), 34.42% (T_4), 34.04% (T_1), 33.73% (T_2), 33.96% (T_{13}) treatments. All these treatments were found statistically at par with each other. The lowest protein content (30.29%) was found in the treatment T_{15} where we did not apply any chemical fertilizer.

Efficient management of nitrogen fertilizers is important for achieving good yield and protein content in the soil. According to Burkitbayev *et al.* (2021) [4], the application of sulphur in powdered form and solute sulphur containing agrochemicals is necessary to boost the yield of soybean seed and increase the protein content in grains. The increase in oil and protein content in soybean due to balanced fertilization, application of S and Micronutrients is also reported by Bairagi *et al.* (2007) [3], Kumar *et al.* (2005) [10], Adkine *et al.* (2011) [1]. Devi *et al.* (2012) [5] reported that Oil and protein content in soybean seeds increased significantly due to application of 75% of RDF through Chemical fertilizers and 25% through vermicompost. Similar findings were also reported by Rana and Badiyala (2014) [14], Patel *et al.* (2014) [12].

Summery and Conclusion

Soybean has been recognized as major food crop since long time that produces 2-3 times more high-quality protein yield per hectare than other legumes and cholesterol free oil. It is mainly grown as a rainfed crop in vertisols of western part of Madhya Pradesh. Balanced application of nutrients play an important roll to improve the productivity of crops along with improved seed and cultural practices. There is a growing awareness amongst the farmers to cultivate the crops under suitable nutrient management system because of escalating cost of chemical fertilizer, decreased soil fertility in respect of secondary and micronutrients. The use of macro and micro nutrients is an important way of improving fertility of the soil. Interaction with many farmers indicated that, in many parts of the western part of Nimar, imbalanced/no use of macro/micro nutrients is encountered resulting into yield reduction to a significant level. Therefore, there is a need to develop suitable nutrient management technology, which can increase crop production and manage nutrient availability of the soil on sustainable basis.

All agronomic practices were done as per standard methods and data collected were subjected to the analysis of variance and least significant difference value were obtained to test the significance of the difference between the treatments at 5% level of significance.

The results obtained from present study are summarized and concluded as below

- Application of 6 tha^{-1} FYM can save 50% chemical fertilizer without any influence on crop productivity.
- The highest seed yield was recorded in T_5 and lowest in T_{15}. T_{15} was found statistically inferior to rest of the treatments, while the treatments T_{10}, T_4, T_6, T_7, T_{10}, T_{11}, T_{13} and T_1 were found statistically at par with each other. The overall results emphasized that recommended dose of N, P, K along with either S, Mo, Zn enhances crop productivity. If we apply FYM @ of 6 t ha^{-1} one can reduce use of chemical fertilizer up to 50% of RDF without sacrificing the seed yield. Sub optimal doses of RDF significantly reduces the seed yield significantly.
- Seed yield data revealed that treatments comprising of soil application of micro nutrient gave higher seed yield when applied with RDF than seed treatment in case of Mo application along with RDF.
- The maximum and minimum Stover yield 3033 and 1807 kg ha^{-1} recorded on pooled basis. During study highest Stover yield was recorded in case of T_5- 20:60:20 kg NPK ha^{-1} + S_{40} and lowest in case of T_{15} Control i.e. where we did not apply any fertilizer. Treatments T_4, T_6, T_7, T_{10} and T_{13} were at par with each other. The treatment T_{15} found statistically inferior to the rest of the treatments under study.

- The effect of various treatments were non-significant on the harvest index of soybean crop. The lowest harvest index was found in case of T_{15} Control treatment.
- The treatments which comprises recommended dose of fertilizer addition of S/Zn/Mo along with RDF further increases oil content but this increase was non-significant.
- Sub optimal doses of fertilizer reduces oil content significantly in soybean crop as compared to other treatments under study.
- Application of FYM 6 t ha^{-1} along with 50% of RDF gave at par oil content to 100% RDF and RDF + S/Zn/Mo. Thus by the addition of organics we can reduce the use of chemical fertilizer up to 50% without affecting soybean oil content significantly.
- If we apply recommended dose of nitrogen only along with Mo/Zn helps to sustain oil content in soybean crop as these treatments were found statistically at par with the treatments which comprised of 100% RDF.
- The oil content in treatment T_4 (RDF + 20 kg S ha^{-1}) and T_5 (RDF + 40 kg S ha^{-1}) were found at par so it seems in these soils if we apply 20 kg S along with RDF is sufficient to sustain oil content in soybean crop.
- Oil yield significantly influenced by the nutrient management. It ranged from 395 to 179 kg ha^{-1} on the basis of pooled analysis.
- The highest oil yield 395 kg ha^{-1} was recorded in treatment T_5 20:60:20 kg NPK ha^{-1} + S_{40} followed by 392 kg ha^{-1} (T_4), 379 kg ha^{-1} (T_{10}), 368 kg ha^{-1} (T_6), 354 kg ha^{-1} (T_7), 350 kg ha^{-1} (T_{13}), 334 kg ha^{-1} (T_{11}) and 337 kg ha^{-1} (T_1).
- The lowest 179 kg ha^{-1} oil yield was observed in T_{15} treatment where no fertilizer was applied.
- Protein content in soybean was influenced significantly by various nutrient management treatments.

Table 1: Effect of nutrient application on growth attributes, yield and harvest index (%) of Soybean crop (pooled of two years)

Treatments	Plant height (cm)	No. of Branches plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	100 Seed wt. (g)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index %
T_1	41.12	3.06	47.63	9.37	11.65	1790.83	2689.8	40.0
T_2	39.60	2.93	47.00	9.12	11.31	1660.17	2502.7	39.9
T_3	37.29	2.79	45.67	8.60	11.27	1388.83	2170.2	39.0
T_4	43.01	3.22	50.13	9.66	12.75	2030.83	3010.7	40.3
T_5	43.65	3.25	53.30	9.84	13.43	2083.00	3033.7	40.7
T_6	42.40	3.20	49.30	9.58	12.42	1956.83	2841.2	40.8
T_7	41.86	3.09	48.87	9.50	12.18	1877.67	2906.5	39.2
T_8	38.91	2.86	46.57	9.03	11.12	1424.17	2222.3	39.1
T_9	37.84	2.87	46.13	9.03	11.02	1420.00	2225.3	39.0
T_{10}	44.27	3.31	51.10	9.95	12.62	2006.00	3008.5	40.0
T_{11}	40.35	3.05	47.43	8.82	11.57	1785.00	2583.7	40.9
T_{12}	38.78	2.90	46.97	9.12	11.23	1481.17	2229.7	41.5
T_{13}	41.58	3.06	47.97	9.47	11.82	1871.00	2850.5	39.6
T_{14}	39.83	3.00	47.33	9.27	11.45	1640.50	2191.7	42.8
T_{15}	36.30	2.74	45.20	8.43	10.45	1098.33	1807.7	37.8
SE(m)±	1.545	0.112	1.366	0.260	0.119	73.46	83.93	1.425
$CD_{(5\%)}$	4.425	0.320	3.912	0.743	0.340	210.36	240.35	NS

Table 2: Effect of nutrient application on oil content, oil yield and protein content of Soybean crop (pooled of two years)

Treatments	Oil content (%)	Oil yield (kgha^{-1})	Protein content (%)
T_1	18.80	337	33.45
T_2	17.65	293	32.90
T_3	17.32	241	30.13
T_4	18.94	392	33.98
T_5	18.99	395	34.38
T_6	18.83	368	36.61
T_7	18.88	354	36.68
T_8	18.59	265	35.34
T_9	18.61	264	31.26
T_{10}	18.91	379	34.53
T_{11}	18.72	334	34.83
T_{12}	17.69	262	31.73
T_{13}	18.72	350	35.58
T_{14}	16.71	274	33.27
T_{15}	16.33	179	30.64
SE(m)±	0.43	16.22	0.998
$CD_{(5\%)}$	NS	46.44	2.859

Conclusion

Over all conclusion drawn from the study that the application of S, Mo and Zn may be recommended along with RDF to achieve higher crop productivity of soybean when grown in Vertisols. Application of 6 t ha^{-1} FYM along with 50% RDF of Chemical fertilizer may be recommended as it gave non-significant differences in case of yield, Growth attributery characters, oil content & its yield and protein content.

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