

Original Research Article

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Response of Rainfed Soybean to Micronutrient Application in Vertisols

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ABSTRACT

The present investigation was carried out in Kharif season during the year 2009 under All India Coordinated Research Project for Dryland Agriculture, College of Agriculture, Indore. A field experiment under rainfed conditions was laid out in randomized block design with twelve treatments at the College of Agriculture Farm, Indore in field No.19 during the Kharif season of 2009. The objectives of the study were: - To evaluate the response of application of micronutrient viz. Zn, Mo, B and Fe to soybean grown in Vertisols under rainfed condition; To evaluate comparative performance of soil and foliar application methods used for micronutrient application; To evaluate the effect of Micronutrient application on physiological processes of soybean such as photosynthesis, respiration, stomatal conductance, leaf temperature, and chlorophyll content. There were twelve treatments and each of them was randomized and replicated three times. The design used in the experiment was randomized block design. 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 4.00 m X 3.20 m. Soybean [*Glycine max* (L.) Merrill] crop (cv. JS-9305) was sown on July 1, 2009. The highest seed yield was recorded in the treatment T5- RDF+ Zn (Soil application) 25 Kg ZnSO₄ (2471 kg ha⁻¹) followed by T3: RDF + Mo (Soil Application) 0.5 kg/ha (2450 kg ha⁻¹), T4: RDF + Mo (Foliar Application) 0.1% Amm. Molybdate (2376 kg ha⁻¹), T9-RDF + Fe (Soil Application)(2353 kg ha⁻¹), T10-RDF + Fe (Foliar Application) (2325, kg ha⁻¹), T7-RDF+ B (Soil Application) (2166kg ha⁻¹), T8-RDF + B (Foliar Application) (2128 kg ha⁻¹), T6-RDF + Zn (Foliar Application) (2209, kg ha⁻¹), T2- Recommended dose of NPKS (2034 kg ha⁻¹), T11- Organic manure @ 10 tha⁻¹ (1831 kg ha⁻¹), and lowest in control (1731, kg ha⁻¹). All the treatments are statistically at par except the treatment T1 and T12 i.e. control and addition of organics alone. Seed yield data revealed that treatments comprising of soil application of micro nutrient gave higher seed yield when applied with RDF than foliar application of micronutrient. This statement is true for all the micro nutrients applied In case of straw yield also. Test weight and chlorophyll content in leaves were also affected significantly by different Treatments. In case of test weight treatments T2 (14.8g) gave the highest test weight. Lowest test weight was recorded in the treatment T1 control. The highest chlorophyll content was recorded in the treatment T3- RDF + Mo (Soil Application) (40.8 SPAD) which was closely followed by the treatment T4-RDF + Mo (Foliar Application) 0.1% Amm. Molybdate, T5-RDF+ Zn (Soil application), T7-RDF+ B (Soil Application). All these treatments were statistically at par with the treatment T3- T2 + Mo (Soil Application). While the treatment T3 was found statistically superior to the rest of the treatments. Soil application of micronutrient was found more economical than foliar application of micro nutrient. The lowest B: C ratio was obtained in case of treatment T12 even less than control (3.26). Higher relative growth rate was observed in the treatments which comprised of application of RDF along with micronutrients as compared to RDF alone and control treatment. The highest RCGR was recorded in the treatment RDF + application of Mo and the lowest in case of control. RDF accumulated lesser dry matter than the treatments which comprised of micronutrient application through soil application. Almost similar trend was observed in case of absolute growth rate. The highest dry matter accumulation was observed in case of RDF + Mo (soil application) and lowest in case of control. RDF accumulated lesser dry matter than the treatments which comprised of micronutrient application through soil application. Almost similar trend was observed in case of dry matter production. The highest no. of nodules per plant (39.6) was recorded in the treatment T3: RDF + Mo (Soil application). This treatment was found significantly superior to rest of the treatments. Lowest numbers of nodules per plant were recorded in control treatment which was found statistically inferior to all the treatment except T12. Agronomic efficiency is enhanced due to application of micronutrients when applied with RDF. Application of FYM alone also gave higher AE than RDF. Lowest AE was recorded in case of farmer's practice where 50 kg DAP was applied per ha. The highest applied recovery efficiency for all the nutrients was recorded in the treatment T3, and lowest in case of Farmer's practice. This emphasized the importance of balance fertilization in enhancing nutrient use efficiency. The highest photosynthesis rate (6.11, μmol CO₂m⁻²s⁻¹) was recorded in the treatment T3- RDF+ Mo soil application, this treatment was found at par with the treatments T4 T5, T6, T7, T8, T9, and T11. Rests of the treatments were significantly inferior to T3 treatment. Application of micronutrients along with RDF enhances photosynthesis rate in soybean crop as compared to RDF alone, farmer's practice, absolute control and FYH alone. The highest transpiration rate was recorded in T3- RDF+ Mo (2.11 μmol H₂O m⁻²s⁻¹), which was found statistically at par with all the treatments except T1, T2, T11 and T12. The transpiration rate recorded in control treatment was found statistically inferior to the rest of the treatments. The stomata conductance commensurate the trends of photosynthesis rate being highest in T3 and lowest in control. This parameter was also affected significantly by different treatments. The water use efficiency has been enhanced due to application of Micronutrients along with RDF as compared to RDF alone, farmer's practice, application of FYM alone @ 10tha-1 and control. Over all conclusion drawn from the study that the application of Mo and Zn may be commended along with RDF to achieve higher crop productivity and crop quality of soybean when grown in Vertisols.

Keywords

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Introduction

Indian agriculture is predominantly rain dependent agriculture covering the 65% of the arable land. Most of the rainfed field has reached a state of maximum impoverishment due to poor management. Economically important crops like pulses, oilseeds are grown largely in dryland followed by millets and cereals. Hence maximum attention needs with respect to micronutrient nutrition in order to boost the productivity of dryland crops. Otherwise these dryland will become impoverished lands. Hence there is need to study the micronutrient status and responses in cereal–pulses based cropping system under dryland Vertisols of Madhya Pradesh for improving productivity and soil health. Hence the above project is submitted to study the micronutrient status, response and management for sustainable productivity to crops and cropping system. Economically important crops like pulses oilseeds are grown largely in drylands followed by millets and cereals.

Hence, maximum attention needs with respect to micronutrient nutrition in order to boost the productivity of dryland crops; otherwise these drylands will become impoverished lands. Therefore, looking to the future need an attempt will be made in this study to evaluate the response of micronutrient application to soybean crop grown in Vertisols under rainfed condition with following objectives: To evaluate the response of application of micronutrient viz. Zn, Mo, B and Fe, to soybean grown in Vertisols under rainfed condition, to evaluate comparative performance of soil and foliar application methods used for micronutrient application and to evaluate the effect of Micronutrient application on physiological processes of soybean such as photosynthesis, respiration, stomatal conductance, leaf temperature, and chlorophyll content.

Materials and Methods

A field experiment under rainfed conditions were laid out in randomized block design with eleven treatments at the research station College of Agriculture Indore during the Kharif season (2009-10). There were eleven treatments and each of them was randomized and replicated three times. The design used in the experiment was randomized block design. The gross plot size was 5 m x 4 m and after leaving non-experimental margin on both sides, the net experimental plot size was 9.0 m x 6.6 m. Soybean [*Glycine max* (L.) Merrill] crop (cv. JS-9305) was sown on July 6, 2009 and harvested on October 13, 2009.

FYM was applied in prescribed treatments at the time of field preparation during rainy season. The requisite quantity of nitrogen, phosphorus, potash and sulphur were applied for different prescribed treatments as basal dose at the time of sowing. S was applied by gypsum which was applied 15 days before sowing as per treatment. Micro nutrient were also applied as basal at sowing time in case of soil application. Foliar application was done at two stages i.e. at three leaves and flowering stage of crop. Analytical techniques and observations, which were adopted for the present studies, are: Plant height, Shoot weight, Test weight, Straw yield –Seed yield and Harvest index

Harvest index (HI) = Economical yield X 100

Composite samples were collected randomly with the help of soil sampling tube before sowing and after harvesting of crop from each plot. Plant sample from each plot were collected randomly at harvesting of soybean crop. The soil sample, which were collected and prepared as mentioned earlier were analyzed. Soil pH was determined in a 1: 2 soil: water suspension by glass electrode Beckman pH meter (Piper, 1966). The soil

suspension used for pH determination was allowed to settle down and conductivity of supernatant liquid was determined by using conductivity meter (Piper, 1950). Available Nitrogen it was determine by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus was determined by using Olsen's extractant (0.5 N sodium bicarbonate solution of pH 8.5, Olsen *et al.*, 1954). Standard solution was prepared by dissolving 0.2195 g of pure dry KH_2PO_4 in one litre of distilled water. This solution contained 50 microgram (0.05 mg) per milliliter. Standard solution was prepared by dissolving 0.2195 g of pure dry KH_2PO_4 in one litre of distilled water. This solution contained 50 microgram (0.05 mg) per milliliter. The transmittance per cent was plotted against microgram of P and standard curve was prepared accordingly. The amount of potassium pre sent in extract was determined by flame photometer as described by Black (1965). The results were calculated as K kg/ha. Available sulphur was determined by the method given by Chesnin and Yien (1951). Methods adopted for different factors involved in plant analysis were as follows: equivalent amount of nitrogen was calculated and results were expressed as content of nitrogen in per cent. The process is described in detail by Piper (1966). One gram of oven dried plant sample was disgusted in acid mixture consisting of concentrated nitric acid and 72% perchloric acid in the ratio of 2:1. The digested material was filtered through Whatman filter paper number 40 and diluted to 100 ml mark. Filtrate was used for determination of phosphorus, potassium and sulphur. The potassium content extract was estimated by flame photometer as described by Black (1965). Determination of sulphur was done by taking 10 ml of aliquot of the filtrate was taken in a 25 ml volumetric flask; 1 ml of 6N HCl (seed solution) and 1 ml of 0.25 per cent gum acacia solution were added to it and shaken. Final volume was made up to

mark with distilled water. Content of the flask were transferred to a beaker and 0.5 g of barium chloride crystals (30 mesh) were added and swirled gently for two minutes. Turbidity produced was measured as transmittance per cent on spectrophotometer at 420 μm . After setting the instrument to 100 reading of transmittance per cent with blank prepared. The amount of sulphur was expressed as S in per cent. Organic carbon content in soil was determined by Walkley and Black's rapid titration method. It was estimated by using the formulae.

$$\text{O.C. (\%)} = \frac{\text{X} - \text{Y}}{2} \times 0.003 \times 100$$

Where,

X = Blank reading

Y = Titrated value.

Water use by the crop was computed using simple water budget method by monitoring surface runoff, deep percolation from 105 cm profile, upward flux of water to root zone if any in tensiometer range and profile moisture content at different times during crop growth period. Sustainable yield index (SYI) was calculating using the following equation.

$$\text{SYI} = \frac{\text{Y} - \text{S.D.}}{\text{Y max}}$$

Where

Y = Estimated average yield of a treatments over years.

S.D. = Estimated Standard Deviation.

Y max = Observed maximum yield (Potential Yield)

Results and Discussion

The influence of micronutrient application on soybean has been evaluated and data are presented in Table 1.

Crop growth parameters *viz.* plant height, no. of branches per plant, TDM and seed yield per plant and pods per plant were recorded at the harvest of crop and data are presented in table 2.

The perusal of the data revealed that the higher relative growth rate was observed in the treatments which comprised of application of RDF along with micronutrients as compared to RDF alone and control treatment. The highest RCGR was recorded in the treatment RDF + application of Mo and the lowest in case of control. The trend observed was RDF + Mo > RDF + B > RDF + Zn > RDF + Fe > RDF and lowest in control. The perusal of the data revealed that all the treatments increased the no. of nodules per plant to that of control. However, the highest no. of nodules per plant (39.6) were recorded in the treatment T3: RDF + Mo (Soil application). This treatment was found significantly superior to rest of the treatments. Nutrient content in the seeds of soybean was determined and data are presented in Table 3.

To compare the nutrient use efficiency of different fertility treatments to two parameters were calculated that is agronomic efficiency of applied nutrients and second one is recovery efficiency and data are presented in Table 4 and 5.

Applied recovery efficiency of each nutrient applied was calculated and data are presented in Table 6.

The plant physiological parameters were recorded using IRGA (infrared gas analyzer) at flowering stage of crop growth and data are

presented in table 7. The data on water use efficiency are presented in Table 8.

Crop yield data of soybean has been affected significantly due to various fertility treatments. The micronutrient application when applied with RDF gave higher seed yield, net return and B:C ratio as compared to RDF without micronutrient application, FYM, 10 t ha⁻¹. The relative effective rate for foliar application is about one-third of that recommended for soil application (Sedberry *et al.*, 1973). In case of Fe foliar application was superior to soil application even up to 200 kg ferrous sulphate ha⁻¹. Generally a 0.5 to 2% solution of FeSO₄·7H₂O is employed and generally more than one spray at an interval of 10-12 days may be required (Sadana and Nayyar, 2000). Sarkar *et al.*, 2006 reported benefits of B application in terms of crop productivity. Gupta, 1979 advocated that B plays an important role in protein synthesis in the meristematic tissue (in root tips, tips of upper plant parts) through its involvement in the synthesis of uracil, which is an essential component of RNA. Thus reduced RNA synthesis (Krueger *et al.*, 1982) and subsequent synthesis of protein leads to disturbance in the development of meristematic tissue and to overcome it a regular supply of B is required. 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). Longevity of residual benefits depends primarily on the initial rate of application; higher rate produce long lasting benefits (Takkar *et al.*, 1997). 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.

Lay Out Plan

T12	T11	T10	T12	T3	T5	T12	T2	T3
T7	T8	T9	T2	T4	T6	T4	T1	T11
T6	T5	T4	T1	T8	T7	T8	T10	T9
T1	T2	T3	T11	T10	T9	T5	T7	T6
R I			R II			R III		

There were twelve treatments given to soybean crop. The details of different treatment combination are as under

T₁	Control i.e. no fertilizer from any source
T₂	Recommended dose of NPKS 20:60:20:40 KG ha⁻¹ N:P:K:S respectively
T₃	T2 + Mo (Soil Application) 0.5 kg/ha (Amm. Molybdate as basal dose)
T₄	T2 + Mo (Foliar Application) 0.1% Amm. Molybdate
T₅	T2+ Zn (Soil application) 25 Kg ZnSO ₄ ha ⁻¹
T₆	T2 + Zn Foliar Application 0.5% Zn
T₇	T7 :T2+ B (Soil Application)
T₈	T8 :T2 + B (Foliar Application)
T₉	T9 :T2 + Fe (Soil Application)
T10	T10 :T2 + Fe (Foliar Application)
T11	T11: Organic manure @ 10 tha ⁻¹
T12	T12: Control

Table.1 Seed yield of soybean as Influenced by soil fertility management

Treat	Parameters							
	yield, kg/ha		HI %	Returns Rs./ha		B:C Ratio	Seed Index (g)	Chlorophyll Content (SPAD)
	Seed	Straw		Gross	Net			
T1	1731	3310	34.3	27700	19700	3.26	11.8	37.95
T2	2034	3924	34.2	32550	23550	3.53	14.8	38.39
T3	2450	3550	40.8	39193	29693	4.13	14.4	40.63
T4	2376	3290	42.0	38023	28523	4.00	13.8	39.17
T5	2471	3529	41.2	39540	30040	4.16	13.9	39.28
T6	2209	3562	39.2	35340	25840	3.72	13.5	37.27
T7	2166	3459	38.5	34663	25163	3.65	13.2	40.01
T8	2128	4123	34.3	34040	24540	3.58	12.5	38.49
T9	2353	3397	41.2	37643	28143	3.96	14.4	38.21
T10	2325	3467	40.2	37193	27693	3.92	12.6	39.29
T11	1974	3901	33.4	31590	22590	3.54	12.3	38.57
T12	1831	3767	32.6	21303	13803	2.84	12.7	37.20
SEm	173.3	303.5	3.28	2773	2733	0.22	0.66	0.68
CD5%	508.4	NS	NS	8133	8133	0.65	1.94	2.01

Table.2 Growth parameters at harvest of soybean as Influenced by soil fertility management

Treatments	Plant height, cm	No. of branches plant ⁻¹	TDM wt plant ⁻¹ , g	Grain wt plant ⁻¹ , g	Pod wt plant ⁻¹
T1	45.33	3.03	19.67	7.97	11.33
T2	54.93	3.67	27.00	10.27	12.47
T3	55.27	3.77	28.80	11.03	15.13
T4	53.27	3.73	28.80	9.83	13.40
T5	55.40	3.87	30.00	11.53	15.30
T6	50.40	3.77	28.60	9.58	13.33
T7	53.60	3.76	28.20	11.33	15.47
T8	53.87	3.70	27.80	10.53	13.60
T9	52.27	3.00	27.70	10.36	15.07
T10	52.87	3.73	27.60	9.87	14.20
T11	51.93	3.71	27.64	9.57	14.37
T12	48.60	3.47	24.20	8.17	12.00
SEm±	38.81	0.37	0.44	0.68	1.06
CD5%	NS	NS	1.28	1.99	3.11

Table.3 Nutrient content (%) in soybean grain

Treatment	N	P	K	S	Zn	Fe	Mo	B
T1	4.66	0.45	3.47	0.28	0.056	0.28	0.32	0.018
T2	5.22	0.58	3.82	0.30	0.070	0.35	0.40	0.023
T3	5.70	0.60	3.92	0.32	0.075	0.36	0.58	0.023
T4	5.25	0.58	3.72	0.31	0.070	0.35	0.53	0.022
T5	5.32	0.58	3.92	0.31	0.089	0.35	0.40	0.022
T6	5.22	0.56	3.72	0.29	0.081	0.32	0.38	0.023
T7	5.30	0.57	3.87	0.30	0.074	0.33	0.39	0.03
T8	5.20	0.57	3.73	0.29	0.071	0.33	0.40	0.029
T9	5.29	0.58	3.82	0.31	0.073	0.41	0.40	0.023
T10	5.17	0.56	3.71	0.29	0.070	0.40	0.38	0.022
T11	5.24	0.55	3.82	0.29	0.074	0.33	0.39	0.021
T12	4.82	0.52	3.58	0.29	0.060	0.29	0.39	0.02

Table.4 Nutrient uptake (kg ha⁻¹) by soybean grain

Treat ment	N-uptake kg ha ⁻¹	P-uptake kg ha ⁻¹	K-uptake kg ha ⁻¹	S-uptake kg ha ⁻¹	Zn-uptake g ha ⁻¹	Fe-uptake g ha ⁻¹	Mo-uptake g ha ⁻¹	B-Uptake g ha ⁻¹
T1	80.63	7.75	60.03	4.80	0.97	4.85	5.54	31.16
T2	106.14	11.75	77.66	6.05	1.42	7.04	8.14	46.79
T3	139.56	14.64	95.96	7.78	1.84	8.82	14.21	56.34
T4	124.70	13.72	88.34	7.31	1.66	8.32	12.60	52.28
T5	130.17	14.27	96.81	7.60	2.20	8.65	9.89	54.37
T6	115.24	12.31	82.11	6.35	1.79	7.07	8.39	50.80
T7	114.77	12.29	83.79	6.44	1.60	7.15	8.45	64.99
T8	110.58	12.07	79.30	6.12	1.51	7.02	8.51	61.70
T9	124.40	13.59	89.81	7.23	1.72	9.65	9.41	54.11
T10	120.12	12.96	86.18	6.68	1.63	9.30	8.83	51.14
T11	103.41	10.81	75.37	5.68	1.46	6.52	7.70	41.46
T12	64.14	6.89	47.63	3.83	0.80	3.86	5.19	36.63
SEm±	9.05	0.97	6.56	0.51	0.126	0.58	0.71	3.99
CD5%	26.54	2.85	19.25	1.50	0.370	1.71	2.09	11.72

Table.5 Agronomic use efficiency

Treatment	Agronomic use efficiency, Kg seed Kg ⁻¹ nutrient applied
T1	-
T2	3.03
T3	7.15
T4	6.45
T5	5.92
T6	4.78
T7	4.26
T8	3.97
T9	5.65
T10	5.94
T11	3.80
T12	3.08

Table.6 Recovery efficiency of applied nutrients

Treatment	N	P	K	S	Zn	Fe	Mo	B
T1	-	-	-	-	-	--	-	-
T2	2.100	0.081	1.502	0.056	0.025	0.318	5.900	7.830
T3	3.771	0.129	2.417	0.099	0.042	0.496	18.040	12.605
T4	3.028	0.114	2.036	0.087	0.034	0.446	14.820	10.575
T5	3.302	0.123	2.459	0.094	0.056	0.479	9.400	11.620
T6	2.555	0.090	1.724	0.063	0.040	0.321	6.400	9.835
T7	2.532	0.090	1.808	0.065	0.032	0.329	6.520	16.930
T8	2.322	0.086	1.584	0.057	0.028	0.316	6.640	15.285
T9	3.013	0.112	2.109	0.085	0.037	0.579	8.440	11.490
T10	2.799	0.101	1.928	0.071	0.033	0.544	7.280	10.005
T11	1.964	0.065	1.387	0.046	0.026	0.266	5.020	5.165
T12	0.825	0.014	0.620	0.024	0.007	0.099	0.700	2.750

Table.7 Effect of fertility management on the physiological parameters of soybean

Treatment	Photo μmolCO ₂ m ⁻² s ⁻¹	Cond molCO ₂ m ⁻² s ⁻¹	Tr μmolH ₂ O m ⁻² s ⁻¹	VpdL (kPa)	T _{leaf} . °C
T1	4.97	238.33	1.59	3.79	31.29
T2	5.55	255.00	1.93	4.40	32.1
T3	6.11	286.00	2.11	4.42	32.21
T4	5.88	280.00	2.06	4.25	32.3
T5	5.90	290.70	2.10	4.34	31.97
T6	5.78	270.80	2.00	4.20	31.7
T7	5.97	285.00	2.07	4.50	32.21
T8	5.80	273.30	2.02	4.30	32.03
T9	6.00	289.00	2.10	4.32	32.1
T10	5.87	274.40	2.03	4.26	31.9
T11	5.48	249.00	1.86	4.00	31.8
T12	4.90	240.60	1.67	3.90	31.86

Table.8 Water use and water use efficiency as influenced by fertility treatments

Treat.	Soil profile moisture in 100 cm depth at sowing (cm)	Soil profile moisture in 100 cm depth at harvest (cm)	Depletion /addition (cm)	Water use, mm	Yield (Kg ha ⁻¹)	WUE (Kg/ha /mm)
T1	40.23	27.23	13	868.7	1731	1.99
T2	40.1	29.56	10.54	866.24	2034	2.35
T3	38.9	29.33	9.57	865.27	2450	2.83
T4	40.2	28	12.2	867.9	2376	2.74
T5	40.8	29.7	11.1	866.8	2471	2.85
T6	41.2	29.8	11.4	867.1	2209	2.55
T7	40.11	29.8	10.31	866.01	2166	2.50
T8	41.2	28.2	13	868.7	2128	2.45
T9	39.4	29.3	10.1	865.8	2353	2.72
T10	41.23	28.9	12.33	868.03	2325	2.68
T11	40.22	28.77	11.45	867.15	1974	2.28
T12	39.89	27.66	12.23	867.93	1831	2.11

Many studies have proven this association (Katyal and Agarwal, 1982; Katyal, 1985; Takkar *et al.*, 1997 and Rattan *et al.*, 1999). Total dry matter plant⁻¹ was maximum in case of T5 (11.53 g) which was found at par with the treatment T3 (28.80 g) and T4 (28.80 g). The trend observed was RDF + Mo > RDF + B > RDF + Zn > RDF + Fe > RDF and lowest in control. Number of workers has reported that application of micronutrients along with N, P and K application enhances crop growth and crop productivity and crop quality also (Katyal and Ponnampurna, 1974). 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). Leaf temperature was not affected significantly by different treatments. Marschner *et al.*, 1986; Bouma, 1969; Berger, 1962; reported that due to micronutrient deficiency and soil moisture

stress in surface soil reduced root growth, reduced transpiration, photosynthesis rate and also mineralization and availability of nutrients.

Summary

The present investigation was carried out in Rabi season during the year 2011-12 under All India Coordinated Research Project for Dryland Agriculture, College of Agriculture, Indore. The details of material used and methodology adopted are given in present chapter. A field experiment was laid out in Randomized block design with nine treatments with three replications. The treatment comprises of nine fertility treatments viz. T₁- N0 P0 - Control, T₂- N20 P13 - Fertilizer N and P at the rate of 20 and 13 Kg ha⁻¹, T₃- N30 P20 -Fertilizer N and P at the rate of 30 and 20 Kg ha⁻¹, T₄- N40 P26 - Fertilizer N and P at the rate of 40 and 26 Kg ha⁻¹, T₅- N60 P35 - Fertilizer N and P at the rate of 60 and 35 Kg ha⁻¹, T₆- FYM 6t ha⁻¹ + N₂₀P₁₃ - Farmyard manure was applied @ 6t ha⁻¹ prior to sowing of soybean plus fertilizer

N and P @ 20 and 13 Kg ha⁻¹, T₇- Residues 5t ha⁻¹ + N₂₀P₁₃ - Crop residues of soybean @ 5t ha⁻¹ as surface mulch in between Crop rows + fertilizer N and P at the rate of 20 and 13 Kg ha⁻¹, T₈. FYM 6tha⁻¹ - Farmyard manure alone @ 6t ha⁻¹, T₉. Residues 5t ha⁻¹ Soybean crop residues alone @ 5t ha⁻¹ after emergence in between crops rows as surface mulch. The gross plot size was 10 m x 7.2 m and after leaving non-experimental margin on both sides, the net experimental plot size was 9.0 m x 6.6 m. Chickpea (*Cicer arietinum* L.) crop (JG-412) was sown on October 16, 2011 and harvested on February 07, 2012. Chickpea seed at the rate of 80 kg per hectare were sown at row-to-row distance of 30 cm and plant to plant distance of about 3 cm at 2 to 3 cm deep in soil.

The micronutrient application when applied with RDF gave higher seed yield, net return and B:C ratio as compared to RDF without micronutrient application, FYM, 10 t ha⁻¹, Farmers practice and Control Treatments. The highest seed yield was recorded in the treatment T5- RDF+ Zn (Soil application) 25 Kg ZnSO₄ (2471 kgha⁻¹) followed by T3: RDF + Mo (Soil Application) 0.5 kg/ha (2450 kgha⁻¹), T4: RDF + Mo (Foliar Application) 0.1% Amm. Molybdate (2376 kgha⁻¹), T9- RDF + Fe (Soil Application)(2353 kgha⁻¹), T10-RDF + Fe (Foliar Application) (2325, kgha⁻¹), T7-RDF+ B (Soil Application) (2166kgha⁻¹), T8-RDF + B (Foliar Application) (2128 kgha⁻¹), T6-RDF + Zn (Foliar Application) (2209, kgha⁻¹), T2- Recommended dose of NPKS (2034 kgha⁻¹), T11- Organic manure @ 10 tha⁻¹ (1831 kg ha⁻¹), and lowest in control (1731, kgha⁻¹). All the treatments are statistically at par except the treatment T1 and T12 i.e. control and addition of organics alone. Seed yield data revealed that treatments comprising of soil application of micro nutrient gave higher seed yield when applied with RDF than foliar application of micronutrient. This statement is

true for all the micro nutrients applied In case of straw yield also. Test weight and chlorophyll content in leaves were also affected significantly by different Treatments. In case of test weight treatments T2 (14.8g) gave the highest test weight. Lowest test weight was recorded in the treatment T1 control. The highest chlorophyll content was recorded in the treatment T3- RDF + Mo (Soil Application) (40.8 SPAD) which was closely followed by the treatment T4-RDF + Mo (Foliar Application) 0.1% Amm. Molybdate, T5-RDF+ Zn (Soil application), T7-RDF+ B (Soil Application). All these treatments were statistically at par with the treatment T3- T2 + Mo (Soil Application). While the treatment T3 was found statistically superior to the rest of the treatments. Soil and foliar application of Mo along with soil application of recommended dose of NPKS enhanced chlorophyll content of soil. Soil application of micronutrient was found more economical than foliar application of micro nutrient. The lowest B: C ratio was obtained in case of treatment T12 even less than control (3.26). The plant height and Number of branches per plant were not affected significantly by different fertility treatments. Higher relative growth rate was observed in the treatments which comprised of application of RDF along with micronutrients as compared to RDF alone and control treatment. The highest RCGR was recorded in the treatment RDF + application of Mo and the lowest in case of control. RDF accumulated lesser dry matter than the treatments which comprised of micronutrient application through soil application. Almost similar trend was observed in case of absolute growth rate. The highest dry matter accumulation was observed in case of RDF + Mo (soil application) and lowest in case of control. RDF accumulated lesser dry matter than the treatments which comprised of micronutrient application through soil application. Almost similar trend was observed in case of dry matter

production. The highest number of nodules per plant (39.6) was recorded in the treatment T3: RDF + Mo (Soil application) this treatment was found significantly superior to rest of the treatments. Lowest numbers of nodules per plant were recorded in control treatment which was found statistically inferior to all the treatment except T12. Zn, Fe, Mo and B uptake was higher in the treatments where these micronutrients were applied as soil application along with RDF followed by the treatment in which these micronutrients were applied through foliar application. Thus, results emphasized that application of micronutrient helps in improving crop quality applied either as soil application or foliar application. Soil application proved better than foliar application. Agronomic efficiency is enhanced due to application of micronutrients when applied with RDF. Application of FYM alone also gave higher AE than RDF. Lowest AE was recorded in case of farmer's practice where 50 kg DAP was applied per ha. The highest applied recovery efficiency for all the nutrients was recorded in the treatment T3, and lowest in case of Farmer's practice. This emphasized the importance of balance fertilization in enhancing nutrient use efficiency. The highest photosynthesis rate ($6.11, \mu\text{molCO}_2\text{m}^{-2}\text{s}^{-1}$) was recorded in the treatment T3- RDF+ Mo soil application, this treatment was found at par with the treatments T4 T5, T6, T7, T8, T9, and T11. Rests of the treatments were significantly inferior to T3 treatment. Application of micronutrients along with RDF enhances photosynthesis rate in soybean crop as compared to RDF alone, farmer's practice, absolute control and FYH alone. The highest transpiration rate was recorded in T3- RDF+ Mo ($2.11 \mu\text{mol H}_2\text{O m}^{-2}\text{s}^{-1}$), which was found statistically at par with all the treatments except T1, T2, T11 and T12. The transpiration rate recorded in control treatment was found statistically inferior to the rest of the treatments. The stomata

conductance commensurate the trends of photosynthesis rate being highest in T3 and lowest in control. This parameter was also affected significantly by different treatments. Leaf temperature was not affected significantly by different treatments. The water use efficiency has been enhanced due to application of Micronutrients along with RDF as compared to RDF alone, farmer's practice, application of FYM alone @ 10tha^{-1} and control. Over all conclusion drawn from the study that the application of Mo and Zn may be recommended along with RDF to achieve higher crop productivity and crop quality of soybean when grown in Vertisols.

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