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## Study the effect of seed inoculation of zinc solubilizing bacteria and zinc fertilization on total uptake of n, p, k and micronutrients by soybean (*Glycine max* L.) and nutrient use efficiency

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### Abstract

The present study entitled, to study the effect of seed inoculation of Zinc solubilizing bacteria and zinc fertilization on total uptake of N, P, K and Micronutrients by soybean and nutrient use efficiency. was carried out during the year 2016-17 at the Department of Soil Science and Agricultural Chemistry, Post Graduate Institute, M.P.K.V. Rahuri. The experiment was contained 11 treatments with 3 replications with randomized block design (RBD). Different sources of zinc, ZnSO<sub>4</sub> and ZnO were applied along with recommended dose of fertilizer and ZnSB (Zinc solubilizing bacteria, The ZnSO<sub>4</sub> and ZnO are applied at different levels 100 percent, 75 percent, 50 percent, and 25 percent. The total uptake of nitrogen was found significantly highest (174.39 kg/ha) in treatment of T4 (100% RDF + 100%RD of Zn through ZnSO<sub>4</sub>+ ZnSB). The total uptake of phosphorus was found significantly highest (16.81 kg/ha) in treatment of T4 (100% RDF + 100%RD of Zn through ZnSO<sub>4</sub>+ ZnSB). The total uptake of potassium was found significantly highest (110.30 kg/ha) in treatment of T4 (100% RDF + 100%RD of Zn through ZnSO<sub>4</sub>+ ZnSB). The results showed non-significant difference in total uptake of micronutrients.

**Keywords:** seed inoculation, zinc solubilizing bacteria, zinc, fertilization, total uptake, *Glycine max* L.

### 1. Introduction

Soybean (*Glycine max* L.) is an important pulse as well as oilseed crop. Soybean is an excellent source of crude protein and oil. It contains 43.2% crude protein and 19.5 % oil. Crude protein of soybean contains lysine (8.4 %) and all other essential amino acids. It also contains 26% carbohydrate, 45% minerals and 2% phospholipids (Halwankar *et al.* 1992) [6]. It is source of vitamin A, B and D. Soybean oil is enriched with vitamin A and lecithin and resembles butter ghee. Soy protein is superior to most of the plant protein by virtue of its high biological value (78.41), protein efficiency ratio (2.47 %) and its essential amino acids pattern resemble to those of cow milk. Soybean therefore has a potential to combat protein calorie malnutrition, in developing countries like India. Soybean flour is used for making bread, biscuits and other foods for diabetic patients. Soybean seed is also used in manufacturing many food products like macaroni, bean curd, soya sauce, green bean, baked bean and soy milk. Soybean is also used for innumerable other products like plastics, paints, glue, linoleum and glycerin. All other plant proteins produce uric acid on digestion (acidic condition) however; soy protein has an alkalizing effect. It is also used as green manure, hay and silage crop. Zinc is one of the most important micronutrients. It plays vital role in the plant life. It has vital role in transformation of carbohydrates, regulation of consumption of sugar and increase source of energy for the production of chlorophyll. Zinc is also required for maintenance of auxin in an active state. The zinc is essential for the synthesis of tryptophan a precursor of auxin. The basic function of zinc in plants relate to metabolism of carbohydrate, protein and phosphate, auxin and ribosome formation. Zinc also indirectly regulates water relations in plants. Lack of auxin due to zinc deficiency results in the failure of cell walls to grow thereby causing high uptake by plants (Price *et al.*, 1972) [12]. Zinc plays an important role in oilseed and legume crops for increasing yield, nodule development and nitrogen fixation (Bhanavase and Patil, 1993) [2].

Zinc deficiencies are generally corrected by applying zinc sulphate or zinc oxide as micronutrient fertilizers. However, very scanty information is available regarding comparative efficacy of these important Zn fertilizers along with zinc solubilizers to field crops in general and legumes in particular.

## 2. Materials and Methods

### 2.1 Collection of soil sample

Before sowing of soybean, the composite representative soil sample was prepared by taking ten soil samples (0 to 22.5 cm) from experimental field for monitoring initial fertility status of experimental plot.

### 2.2 Collection of plant samples of soybean

Soybean samples at 30 DAS and 60 DAS and straw and grain samples after harvest from each treatment were collected for analysis, dried and stored well by labeling for subsequent analysis.

### 2.3 Field operations

All cultural practices for soybean crop were followed timely so as to maintain required growth.

### Field experimental details

**Table 1:** Experimental details

1.	Location	PGI Research Farm, MPKV, Rahuri.
2.	Year of start	2016-17
3.	Crop	Soybean
4.	Soil type	Medium deep black soil (Inceptisol)
5.	Season	Kharif
6.	Variety	Phule Agrani
7.	Treatments	11
8.	Replications	3
9.	Design	Randomized Block Design
10.	Plot size	Gross plot: 3.60 m x 3.20 m Net plot: 3.00 m x 2.80 m
11.	Spacing	30 cm X 10 cm

**Table 2:** Treatment details

T <sub>1</sub>	Absolute control
T <sub>2</sub>	ZnSB alone
T <sub>3</sub>	100% RDF alone
T <sub>4</sub>	100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB
T <sub>5</sub>	100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB
T <sub>6</sub>	100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB
T <sub>7</sub>	100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB
T <sub>8</sub>	100% RDF + 100%RD of Zn through ZnO+ ZnSB
T <sub>9</sub>	100% RDF + 75%RD of Zn through ZnO + ZnSB
T <sub>10</sub>	100% RDF + 50%RD of Zn through ZnO + ZnSB
T <sub>11</sub>	100% RDF + 25%RD of Zn through ZnO + ZnSB

**Note:** - Seed treatment of ZnSB @ 5% to seed was given at the time of sowing and 5% through drenching at 30 DAS.

2) GRDF at 50:75:45 kg ha<sup>-1</sup> + 5 t ha<sup>-1</sup> FYM was common to all except T<sub>1</sub> and T<sub>2</sub>.

3) 100 % RD of ZnSO<sub>4</sub> is 20 kg ha<sup>-1</sup> (4.2 kg Zinc ha<sup>-1</sup>).

### 2.5 Methods of application of manures and fertilizers

The fertilizers were applied to experimental plots as a basal dose to soybean as per treatments. The recommended fertilizer dose for soybean was applied to experimental plot as per treatment through band placement using Urea, SSP, MOP as a source of N, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O.

The Zinc solubilizing bacteria applied @ 5% to seed at sowing and 5% in water through drenching at 30 DAS.

### 2.6 Seed

The seed of the soybean (*cv. Phule agrani*) was procured from the Department of Soil Science and Agril. Chemistry, MPKV, Rahuri.

### 2.7 Collection of plant samples of soybean

Soybean samples at 30 DAS and 60 DAS and straw and grain samples after harvest from each treatment were collected for analysis, dried and stored well by labeling for subsequent analysis.

### 2.8 Details of the field operations

The details of field operations which were carried out during the period of field experimentation on soybean are presented in table 1.

### 2.9 Growth studies

#### 2.9.1 Plant height

Height of plant generally indicates the growth of a crops. The observations on plant height of soybean were recorded from the 30<sup>th</sup> days and 60<sup>th</sup> days. It was measured in cm from the ground level up to the base of the terminal leaf bud on the main stem.

#### 2.9.2 Number of pods per plant

The total number of pods from selected five sampled soybean plants was counted. The mean number of pods per plant was calculated.

#### 2.9.3 Grain and straw yield per hectare

The grain yield per hectare (q ha<sup>-1</sup>) was recorded after threshing of all plants from the net plot. The grain yield in quintals per hectare was worked out from the yield of grains per net plot.

The straw yield per net plot was obtained by subtracting seed yield from biological yield of respective net plot. Then straw yield per hectare was worked out from the straw yield per net plot.

### 2.9.4 Chemical studies

#### 2.9.4.1 NPK content in plants (Nutrient concentration).

The total NPK concentration in plants was estimated at harvest by using standard methods of analysis as given in table 1.

#### 2.9.4.2 NPK uptake

The uptake of nitrogen, phosphorus and potassium by plant was calculated by multiplying per cent nitrogen, phosphorus and potassium content in plant with their respective dry matter yield.

## 3. Results and Discussions

### Nutrient concentration (NPK) at 30 DAS.

The data regarding the nutrient concentration in soybean plants are presented in table 3. The data revealed that the nutrient concentration was significantly influenced by zinc application through zinc sulphate and zinc oxide (Table 3).

Further, it can be seen from table 3, that the application of Zinc @ 20, 15, 10,5 kg ha<sup>-1</sup> either through zinc sulphate or zinc oxide were at par in respect of nitrogen, phosphorus and potassium concentration in soybean plants at 30 DAS and significantly superior over no zinc application. Numerically, however the nitrogen concentration was more in 10 kg Znha<sup>-1</sup> through zinc oxide (1.66 %) followed by 15 kg Znha<sup>-1</sup> and 20 kg Znha<sup>-1</sup> through zinc oxide (1.64 % and 1.55 %).

The numerical values of phosphorus and potassium concentration were more in the treatment, where 20 kg Zn ha<sup>-1</sup> through zinc sulphate was applied (0.07 and 0.18 %).

The magnitude of nutrient concentration in soybean at 30 DAS was not distinguishable to differentiate the effect due to levels of zinc and their sources. However, the significant lower nutrient concentrations were observed in treatment where no Zn was applied. These observation indicate that the application of zinc either through zinc sulphate or zinc oxide had positive role to enhance the nutrient concentration. The

results are in confirmation with those reported by Kumar and Singh (1980)<sup>[10]</sup>.

The increased nutrient concentrations in soybean at 30 DAS can be attributed to the synergism between the native phosphorus and added zinc resulted in increased availability of phosphorus. The added zinc to soybean might have stimulated the symbiotic process in soybean rhizosphere due to increased activities of micro-organisms which, inturn increased the nitrogen concentration in plant.

**Table 3:** Concentration of nutrient in soybean plant at 30 DAS as influenced by application of Zn solubilizer and fertilizer to soybean on Inceptisol.

Treatments	Concentration of nutrients (%)		
	N	P	K
T <sub>1</sub> : Absolute control	1.45	0.05	0.12
T <sub>2</sub> : ZnSB alone	1.49	0.06	0.14
T <sub>3</sub> : 100% RDF alone	1.41	0.06	0.15
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.48	0.07	0.18
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.54	0.06	0.13
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.49	0.06	0.13
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.59	0.07	0.13
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	1.55	0.07	0.14
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	1.64	0.06	0.13
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	1.66	0.05	0.14
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	1.58	0.06	0.13
SEm (±)	0.02	0.002	0.01
CD at 5%	0.07	0.006	NS

#### Micronutrient concentration

The data pertaining to micronutrient concentration of soybean plants at 30 DAS as influenced by zinc application through zinc sulphate and zinc oxide are presented in table 4.

On critical observation of the data presented in table 4 revealed that the application of zinc through zinc sulphate and zinc oxide increased the concentration of iron, manganese, zinc and copper in soybean plant at 30 DAS. The magnitude of increase in iron and manganese concentration in soybean plants due to the graded levels of zinc irrespective of their sources was more or less similar. Whereas, the concentration of copper at 20 kgha<sup>-1</sup> zinc application through ZnO (25.70 mgkg<sup>-1</sup>) and ZnSO<sub>4</sub> (24.80 mgkg<sup>-1</sup>) was significantly higher than 10 kgha<sup>-1</sup> zinc application through ZnO (23.40mgkg<sup>-1</sup>) and ZnSO<sub>4</sub> (25.20 mgkg<sup>-1</sup>). The treatments of 20 kgha<sup>-1</sup> zinc application through ZnSO<sub>4</sub> and ZnO were intermediate in influencing the copper concentration as compared to their higher and lower level of zinc application.

The higher zinc concentration showed an antagonistic effect on copper content of soybean plants might be probably due to the reduction of copper concenuration in soybean plants at

higher levels of zinc pplication.

The iron content of soybean plants at 30 DAS stage was increased with an increase in zinc application. The application of ZnSO<sub>4</sub> as a source of Zinc @ 20 kgha<sup>-1</sup> recorded the highest (166.0 mgkg<sup>-1</sup>) iron content in soybean at 30 DAS over rest of the treatments. This observation was indicative of the fact that the application of zinc @ 15 kgha<sup>-1</sup> either through ZnSO<sub>4</sub>or ZnO was in the safe limit as far as iron concentration of soybean is concerned at 30 DAS.

The manganese concentration in soybean was increased numerically with an increase in the levels of zinc. Application of zinc@ 10 kg ha<sup>-1</sup> through zinc sulphate resulted in higher concentration of manganese (46.60 mgKg<sup>-1</sup>), which was on par with 15 kgha<sup>-1</sup> ZnSO<sub>4</sub> (44.30) and 5 and 10 kg ZnO (46.30).

Further, it is of interest to know that the zinc concentration in soybean was also significantly increased with an increase in the levels of zinc. Maximum zinc concentration (40.80 mgkg<sup>-1</sup>) was seen at 20 kg Znha<sup>-1</sup> application through zinc oxide was on par with the application of 10 kg Znha<sup>-1</sup>through ZnO. These results are in accordance with the results of Gupta and Singh (1986)<sup>[5]</sup>.

**Table 4:** Concentration of micronutrient in soybean plant at 30 DAS as influenced by application of Zn solubilizer and fertilizer to soybean on Inceptisol.

Treatments	Concentration of micronutrients (mgkg <sup>-1</sup> )			
	Fe	Mn	Zn	Cu
T <sub>1</sub> : Absolute control	154	40.70	32.20	22.20
T <sub>2</sub> : ZnSB alone	156	41.20	32.10	22.70
T <sub>3</sub> : 100% RDF alone	160	40.00	34.40	21.20
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	166	43.00	35.20	24.80
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	164	44.30	32.10	24.30
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	160	46.60	31.60	25.20
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	158	46.30	38.00	25.40
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	165	46.30	40.80	25.70
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	162	41.00	34.70	23.80
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	164	42.60	39.50	23.40
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	160	42.20	37.10	22.20

SEm ( $\pm$ )	3.14	0.90	0.71	0.43
CD at 5%	NS	2.65	2.12	1.27

### Nutrient concentration of NPK at 60 DAS.

The data regarding the nutrient concentration in soybean plants are presented in table 5. A close look to the data revealed that the nutrient concentration significantly influenced by zinc application through zinc sulphate and zinc oxide.

Further, it can be seen from Table 5, that the application of Zinc @ 20, 15, 10,5 kgha<sup>-1</sup> either through zinc sulphate or zinc oxide were at par in respect of nitrogen, phosphorus and potassium concentration in soybean plants at flowering stage and significantly superior over no zinc application. Numerically, however the nitrogen concentration was more in 5 kg Znha<sup>-1</sup> through zinc sulphate (1.98 %) which was on par with 10 kg Znha<sup>-1</sup> (1.97 %) through ZnSO<sub>4</sub> followed by 15 kg Znha<sup>-1</sup> and 20 kg Znha<sup>-1</sup> through ZnSO<sub>4</sub> (1.96 %).

The numerical values of phosphorus concentration was more in the treatment, where 20 kg Znha<sup>-1</sup> through zinc sulphate was applied (0.10 %) followed by 10 kg ZnO (0.09 %) and ZnSB alone (0.09). however, the nutrient concentration of potassium

in soybean at 60 DAS was found non-significant. However numerically higher potassium concentration in 10 kg ZnSO<sub>4</sub> and 5 kg ZnO.

The magnitude of nutrient concentration in soybean at 60 DAS was not distinguishable to differentiate the effect due to levels of zinc and their sources. However, the significant lower nutrient concentrations were observed in treatment where no Zn was applied. These observation indicate that the application of zinc either through zinc sulphate or zinc oxide had positive role to enhance the nutrient concentration. The results are in confirmation with those reported by Kumar and Singh (1980)<sup>[10]</sup>.

The increased nutrient concentrations in soybean at 60 DAS can be attributed to the synergism between the native phosphorus and added zinc resulted in increased availability of phosphorus. The added zinc to soybean might have stimulated the symbiotic process in soybean rhizosphere due to increased activities of micro organisms which, inturn increased the nitrogen concentration in plant.

**Table 5:** Concentration of nutrient in soybean plant at 60 DAS as influenced by application of Zn solubilizer and fertilizer to soybean on Inceptisol.

Treatments	Concentration of nutrients (%)		
	N	P	K
T <sub>1</sub> : Absolute control	1.72	0.08	0.18
T <sub>2</sub> : ZnSB alone	1.80	0.09	0.19
T <sub>3</sub> : 100% RDF alone	1.88	0.08	0.18
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.88	0.10	0.19
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.96	0.07	0.19
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.97	0.06	0.20
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1.98	0.07	0.18
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	1.93	0.08	0.19
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	1.93	0.07	0.18
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	1.90	0.09	0.18
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	1.91	0.08	0.20
SEm ( $\pm$ )	0.04	0.002	0.008
CD at 5%	0.07	0.006	NS

### Micronutrient concentration

The data pertaining to micronutrient concentration of soybean plants at 60 DAS as influenced by zinc application through zinc sulphate and zinc oxide are presented in Table 6.

On critical observation of the data presented in Table 6 revealed that the application of zinc through zinc sulphate and zinc oxide increased the concentration of iron, manganese, zinc and copper in soybean plant at 60 DAS. The magnitude of increase in iron and manganese concentration in soybean plants due to the graded levels of zinc irrespective of their sources was more or less similar. Whereas, the concentration of copper at 20 kgha<sup>-1</sup> zinc application through ZnO (27.20 mgkg<sup>-1</sup>) and ZnSO<sub>4</sub> (26.70 mgkg<sup>-1</sup>) was significantly lower than due to 10 kgha<sup>-1</sup> zinc application through ZnO (27.70 mgkg<sup>-1</sup>) and ZnSO<sub>4</sub> (26.80 mgkg<sup>-1</sup>). The treatments of 20 kgha<sup>-1</sup> zinc application through ZnSO<sub>4</sub> and ZnO were intermediate in influencing the copper concentration as compared to their higher and lower level of zinc application.

The higher zinc concentration showed an antagonistic effect on copper content of soybean plants might be probably due to the reduction of copper concentration in soybean plants at higher levels of zinc application.

The iron content of soybean plants at 60 DAS stage was increased with an increase in zinc application. The application of ZnSO<sub>4</sub> as a source of Zinc @ 20 kgha<sup>-1</sup> recorded the highest (170.0 mgkg<sup>-1</sup>) iron content in soybean at 60 DAS over rest of the treatments. however, the result showed non-significant results. This observation was indicative of the fact that the application of zinc @ 20 kg ha<sup>-1</sup> either through ZnSO<sub>4</sub> or ZnO was in the safe limit as far as iron concentration of soybean is concerned at 60 DAS.

The manganese concentration in soybean was increased numerically with an increase in the levels of zinc. Application of zinc @ 20 kgha<sup>-1</sup> through zinc oxide resulted in higher concentration of manganese (49.40 mgkg<sup>-1</sup>). Which was at par with application of Zn @ 5 kgha<sup>-1</sup> through ZnSO<sub>4</sub> and 10 kgha<sup>-1</sup> ZnSO<sub>4</sub>.

Further, it will of interest to know that the zinc concentration in soybean was also significantly increased with an increase in the levels of zinc. Maximum zinc concentration (42.0 mgkg<sup>-1</sup>) was seen at 20 kg Znha<sup>-1</sup> application through zinc oxide. These results are in accordance with the results of Gupta and Singh (1986)<sup>[5]</sup>. Which was on par with 20 kgha<sup>-1</sup> Zn application through ZnSO<sub>4</sub> (41.0) and 15 kgha<sup>-1</sup> Zn application through ZnSO<sub>4</sub> and 15 and 10 kgha<sup>-1</sup> ZnO.

**Table 6:** Concentration of micronutrient in soybean plant at 60 DAS as influenced by application of Zn solubilizer and fertilizer to soybean on Inceptisol.

Treatments	Concentration of micronutrients (mgkg <sup>-1</sup> )			
	Fe	Mn	Zn	Cu
T <sub>1</sub> : Absolute control	160	42	32	24.30
T <sub>2</sub> : ZnSB alone	162	43.2	35	25.50
T <sub>3</sub> : 100% RDF alone	164	42.10	34	22.70
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	170	44.40	41	26.70
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	167	45.30	40	26.90
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	168	48.10	38	26.80
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	164	48.20	31	28.30
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	166	49.40	42	27.20
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	162	43.30	40	25.60
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	160	44.80	39	27.70
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	162	43.40	36	23.80
SEm (±)	2.39	1.20	1.01	1.05
CD at 5%	NS	3.54	3.00	3.10

### Nutrient uptake (NPK)

The data regarding the nutrient uptake (NPK) by soybean at harvest as influenced by zinc application through zinc sulphate and zinc oxide are presented in table 7 and graphically depicted through fig.

The data revealed that application of zinc to soybean had significant effect on the uptake of nitrogen, phosphorus and potassium by soybean at harvest which were on par due to application of zinc @ 15 and 10 kgha<sup>-1</sup> through zinc sulphate and zinc oxide. It is interesting to note that the application of zinc sulphate @ 20 kgha<sup>-1</sup> as a source of zinc to soybean recorded significantly highest nitrogen uptake (174.39 kgha<sup>-1</sup>), however this treatment is on par with the 20 kg Znha<sup>-1</sup> through ZnO (164.21kgha<sup>-1</sup>). phosphorus uptake (16.81 kgha<sup>-1</sup>) and potassium uptake (110.30 kg ha<sup>-1</sup>). It can be seen from the data presented in table 7 that the higher levels of zinc

application were not much effective over their lower levels either through zinc sulphate or zinc oxide.

Results are in accordance with Tripathi *et al.* (1999) and Bahl *et al.* (1996) who reported contradictory evidences regarding the effect of zinc on uptake, translocation and contents especially for phosphorus.

The total uptake of phosphorus was significantly influenced by the application of 20 kg Zn through ZnSO<sub>4</sub> and ZnO. The application of 20 kg Znha<sup>-1</sup> recorded significantly higher uptake of phosphorus where as it was on par with (14.85) the application of 15 kgha<sup>-1</sup> Zn through ZnSO<sub>4</sub> and 100% RDF alone (16.81).

The total uptake of potassium in soybean after harvest was significantly influenced by the application of levels of zinc through ZnSO<sub>4</sub> and ZnO. The application of 20 kgha<sup>-1</sup> Zn through ZnSO<sub>4</sub> recorded significantly higher uptake of potassium (110.30) which was on par with T<sub>8</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>3</sub>.

**Table 7:** Total uptake of nutrients as influenced by application of Zn solubilizer and fertilizer to soybean on Inceptisol.

Treatments	Total uptake of nutrients (kgha <sup>-1</sup> )		
	N	P	K
T <sub>1</sub> : Absolute control	99.26	8.20	57.18
T <sub>2</sub> : ZnSB alone	99.28	9.06	59.54
T <sub>3</sub> : 100% RDF alone	158.38	14.52	98.94
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	174.39	16.81	110.30
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	159.81	14.85	101.04
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	151.65	13.66	100.73
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	149.08	12.10	93.03
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	164.21	15.30	103.54
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	151.52	12.97	97.43
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	144.05	11.75	96.59
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	140.82	11.43	87.15
SEm (±)	4.75	0.86	4.34
CD at 5%	14.02	2.56	12.83

### Micronutrient uptake

The data regarding the micronutrient uptake by soybean are presented in table 8. It can be seen that uptake of all the micronutrients was significantly influenced by zinc application through zinc sulphate and zinc oxide.

The increased levels of zinc application recorded the linear increase in the uptake of manganese, zinc and copper. The decreased uptake of iron by soybean due to graded levels of application could be attributed to antagonistic relation of Zn with iron.

The uptake of iron was significantly highest in application of zinc through 20 kgha<sup>-1</sup> ZnSO<sub>4</sub>(1604.27), however which was on par with T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>9</sub>.

The uptake of manganese was significantly highest in application of zinc through 20 kgha<sup>-1</sup> ZnSO<sub>4</sub> (1198.11), however which was on par with T<sub>3</sub>, T<sub>5</sub>, T<sub>6</sub>, T<sub>8</sub>, T<sub>9</sub>, T<sub>10</sub>.

The uptake of zinc was significantly highest in application of zinc through 20 kgha<sup>-1</sup> ZnO (334.83), however which was on par with T<sub>4</sub>, T<sub>5</sub>, T<sub>9</sub>.

The uptake of copper was significantly highest in application of zinc through 20 kgha<sup>-1</sup> ZnO (116.18), however which was on par with T<sub>4</sub>. Similar observation was reported by Duraisamy *et al.* (1988) [4]. These observations are also in close agreement with the results reported by Brown and Tiffin (1962) [3] who observed iron deficiency in corn and millets due to application of zinc.

**Table 8:** Total uptake of micronutrient as influenced by Zinc solubilizer and zinc fertilizer on nutrient uptake, yield and quality of soybean on Inceptisol.

Treatments	Total uptake of micronutrient at harvest (g ha <sup>-1</sup> )			
	Fe	Mn	Zn	Cu
T <sub>1</sub> : Absolute control	1005.12	734.12	197.14	68.42
T <sub>2</sub> : ZnSB alone	992.56	737.45	198.67	68.07
T <sub>3</sub> : 100% RDF alone	1489.86	1125.86	303.04	103.76
T <sub>4</sub> : 100% RDF + 100%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1604.27	1198.11	325.08	111.13
T <sub>5</sub> : 100% RDF + 75%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1543.23	1156.47	313.28	106.93
T <sub>6</sub> : 100% RDF + 50%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1504.19	1122.16	304.62	103.39
T <sub>7</sub> : 100% RDF + 25%RD of Zn through ZnSO <sub>4</sub> + ZnSB	1364.15	1069.96	286.33	99.02
T <sub>8</sub> : 100% RDF + 100%RD of Zn through ZnO+ ZnSB	1574.01	1190.47	334.83	116.18
T <sub>9</sub> : 100% RDF + 75%RD of Zn through ZnO + ZnSB	1500.20	1119.85	314.13	106.41
T <sub>10</sub> : 100% RDF + 50%RD of Zn through ZnO + ZnSB	1463.26	1113.64	308.30	105.59
T <sub>11</sub> : 100% RDF + 25%RD of Zn through ZnO + ZnSB	1381.00	1017.46	286.19	94.91
SEm (±)	37.82	30.49	8.51	2.57
CD at 5%	112.36	90.59	25.29	7.64

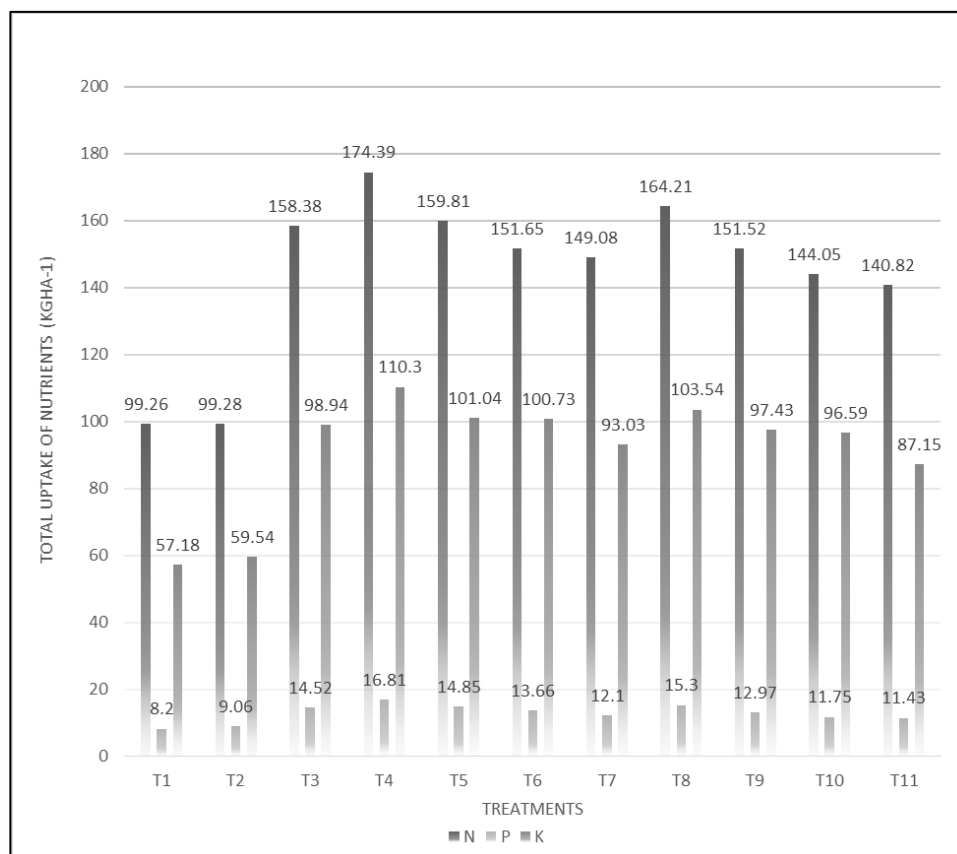
#### 4. Conclusion

It is concluded that 100% RD of Zn through ZnSO<sub>4</sub> @ 20 kg ha<sup>-1</sup> along with general recommended dose of fertilizer (50:75:45 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O kg ha<sup>-1</sup> + 10 t ha<sup>-1</sup> FYM) with the 5% ZnSB treatment to seed at the time of sowing as well as drenching at 30 DAS to soybean was found beneficial for

increasing total uptake of N, P, K, and micronutrients, agronomic efficiency in soybean on Inceptisol.

#### 5. Acknowledgements

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**Fig 1:** Total uptake of nutrients as influenced by application of zinc solubilizer and zinc fertilizer to soybean on inceptisol.



**Fig 2:** General view of experimental plot

## 6. References

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