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ABSTRACT

Experiments were conducted in two locations under the acidic soil conditions of Nagaland. Growth, yield, yield attributes and quality of soybean were recorded, analysed and computed statistically during 2019, 2020 and pooled respectively. It was observed that the parameters such as plant height, no. of nodules plant^{-1}, fresh weight of nodules, dry weight of nodules, seeds pod^{-1}, pods plant^{-1}, seed and stover yield, protein content and yield, oil content and yield and soil fertility after harvest were significantly increased @ 5 kg ha^{-1} $ZnSO_4$ H_2O + RDF during both the experimental years as well as in pooled respectively. The fatty acids composition in soybean such as palmitic, stearic, oleic, linoleic and linolenic acid were also found to be significantly increased @ 5 kg ha^{-1} $ZnSO_4$ H_2O + RDF among the various Zn sources applied. From the experiment conducted, it was observed that soybean responded well to application of Zinc sources in balanced doses.

1. INTRODUCTION

Soybean is a leguminous crop which can adapt on a diverse range of agro-climatic conditions and soils. In India, total area under cultivation of soybean is 113.339 lakh ha with a productivity of 114.832 lakh tons [36]. The leading soybean growing states in India are Madhya Pradesh, Rajasthan, Andhra Pradesh, Karnataka, Chhattisgarh and Gujarat, respectively. Out of which, about 53% of the soybean growing area in India is concentrated in the state of Madhya Pradesh. In Nagaland, soybean is grown as a rain fed crop in almost all the districts of the state irrespective of elevation and irrigation facilities. The total area under cultivation of soybean in Nagaland is 25040 ha with a productivity of 1.25 MT ha^{-1} [35]. A steady increased in the production, exports, imports and consumption of soybean oil has been noticed each year. The world production and consumption of soybean oil in million metric tons is 360.08 and 57.05, respectively [34]. Soybean crops used not only as an oilseed crop but it is used as feeds of fodder, forage and silage for livestock and poultry. It is processed and used as a by products such as soymilk, soy flour, soy protein, tofu and fermented food products for human consumption [33]. However, people of Nagaland consumed it traditionally as a food since time immemorial.

For the cultivation of soybean, application of zinc is considered an essential component which helps in the formation of protein and enzymes. Its deficiency retards plant growth and yield. Zinc in small quantity plays a vital role in various physiological functions such as photosynthesis, reproduction, growth regulation and resistance from diseases [24]. Zinc deficiency is found wide spread recently in the oilseed growing states particularly Madhya Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh, Karnataka and Uttar Pradesh [25]. Zinc deficiency is expected to increase to about 63 % by 2025 owing to continuous depletion of soil fertility in India [31]. Zinc deficiency is also prevalent in Nagaland lately which may be due to shifting cultivation, leaching, and continuous cropping without replenishing the soil fertility in this region [5]. Zinc deficiency is found in soils where low availability of zinc is prevalent which thereby decreases the crop yield and its quality. The researchers have also found positive effect of zinc sulphate application on traits such as oil seed yield.

In quality aspects, soybean contains all essential amino acids (except methionine) [32] which must be supplied in the diet because they cannot be synthesized by the human body. Proteins and lipids, some vitamins and minerals are some major nutritionally important components of soybean which is limiting in the sulphur containing amino acids for most animal species, including humans but contain sufficient lysine to overcome the lysine deficiency of cereals. The amount of protein in soybean (30-44%) is greater than the protein content in legume (20-30%) and in cereals [32]. Soybean oil provides calories, essential fatty acids and vitamins A and E but contributes insignificant amount of vitamin D and K [6]. The fatty acid molecules known as Omega-3 includes Alpha-linolenic acid (ALA) and linolenic acid. The fatty acid such as linoleic acid is found in soybean in considerable amount and it is a precursor of its longer chain fatty acid which is a derivative of arachidonic acid. However, the information on the micronutrient availability and its effects in crop yield and quality is still limited in this region. Considering all these facts, the experiment wasconducted to review the oil content and fatty acid composition in soybean seed as influenced by various zinc sources under fine typic Kanhapludalf.

2. MATERIALS AND METHODS

The experiment was conducted at the experimental research farm of School of Agricultural Science and Rural Development (SASRD), Medziphema Campus, Nagaland University, Medziphema, Nagaland, India during the year 2019 and 2020. The experimental plots contains initial soil status value of pH was 5.72, EC 0.22 dsm^{-1}, OC 0.50 %, CEC 12.66 Cmol (p+) kg^{-1}, N (206.21 kg ha^{-1}), P (14.15 kg ha^{-1}), K (108.67 kg ha^{-1}), Zn (0.20 ppm) respectively. In the second year, pH value was 5.68, EC 0.23 dsm^{-1}, OC 0.52 %, CEC 13.18 Cmol (p+) kg^{-1}, N (219.10 kg ha^{-1}), P (14.29 kg ha^{-1}), K (119.12 kg ha^{-1}) and Zn (0.22 ppm). The soil textural class was sandy clay loam belonging to Alfisols classified under family fine typic Kanhapludalf. The yield and yield attributing traits data viz., plant height, no. of nodules $plant^{-1}$, fresh weight of nodules, dry weight of nodules, seeds pod^{-1}, pods $plant^{-1}$, seed and stover yield were recorded during both the experimental year and the quality traits such as protein, oil content and fatty acids and soil fertility were also assessed. The experiment was formulated with Randomised Block Design consisting of sixteen treatments and three replications. The variety used was JS 97-52. The sources of zinc substrate used were $ZnSO_4$ $7H_2O$ @1, 2.5, 5 kg ha^{-1}, $ZnSO_4H_2O$ @ 1, 2.5, 5 kg ha^{-1}, Zn-EDTA @1, 2.5, 5 kg ha^{-1}, liquid ZnO @ 300, 600, 900 ml ha^{-1}. Recommended dose of fertilizer was applied @ 20: 60: 40: 30: 1.5 (N: P: K: S: B) in all the plots irrespective of the treatment. Lime as an amendment was also added @ 1/10 of LR before 20 days of sowing. The available nitrogen in soil was determined using alkaline potassium permanganate method as described. The available phosphorus in soil was determined and the available potassium in soil was

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determined by flame photometric method using neutral normal ammonium acetate (pH 7.0). The available Zinc in the soil was also determined by DTPA extraction and AAS method. The protein content in seeds was calculated for each treatment by multiplying the seed N by a factor of 6.25. Oil extraction was done using the method described. The identification and quantification of fatty acid was done by forming their methyl esters. The methyl esters prepared were estimated as relative percentage of fatty acid profile by Gas Chomatography (GLC). The esters were analyzed using M/s Nucon Engineers AMIL Gas Chromatograph (Solid state) model: 5765 or equipped with a flame ionization detector fitted with a 6' x 1/8' stainless steel column, 6% BDS (Butane diol succinate) on 100-120 mesh chromosorb HP. The condition for separation was as follows: Oven temperature: 190-2000C; injector and flame ionization detector temperature: 240 and 2500C; hydrogen flow rate 40ml min^{-1}; nitrogen flow rate 30ml min^{-1}. The identification of the peaks was done by comparing their retention time with those of standard fatty acid esters. The data recorded were statistically analysed using the F-test.

3. RESULTS AND DISCUSSION

The data on yield and yield attributing parameters were recorded significantly with increasing levels of various zinc sources which are depicted in table 1. The plant height recorded significant increased with application of zinc input in both the experimental year and pooled. The maximum plant height at maturity obtained was 36.87, 36.91 and 36.89 cm respectively @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF. The increment in plant height occurred might be due to zinc use resulting in higher shoot growth due to cell elongation, differentiation and apical dominance [39]. Similarly, the nodule formation at flowering stage was found to be significantly increased and the highest no. of nodules $plant^{-1}$ recorded in both the year and pooled were 46.70, 45.10 and 45.90 respectively at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF while the lowest was recorded in control. [8], [15] also obtained similar kind of results, where Zn fertilization @ 5 Zn kg $ha^{-1}$was used. The data obtained over the fresh weight and dry weight are given in the table 1. The fresh and dry weight of nodules were significantly increased with zinc treatment and the maximum observed was 0.36, 0.37, 0.37 g and 0.13, 0.12, 0.13 g @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF during both the years and pooled. The lowest was recorded at control. [16], [9] also reported significant increase in fresh weight of nodules $plant^{-1}$ with Zn application @5 kg Zn ha^{-1} in summer cluster bean and 75 mg Zn g^{-1}in horse gram. This increased in nodulation might be due to the enhanced rooting system with the application of Zn.

It was observed that application of zinc sources significantly increased the no. of pods $plant^{-1}$ and the seeds pod^{-1} as shown in table 2. The highest no. of pods $plant^{-1}$ recorded during the consecutive years and pooled were 104.30, 107.20 and 105.75 @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF. The lowest was recorded at control (76.30, 63.30 and 68.80). [23], [37] also reported significant improvement in the number of pods $plant^{-1}$ @ 10 kg Zn ha^{-1} in mungbean and dry bean @ 25 kg ha^{-1}. This increased in the no. of pods $plant^{-1}$ with zinc application might be due to the role of zinc in enhancing roots, fruiting, growth and development of a plant [10]. The highest no. of seeds pod^{-1} recorded was 3.93, 3.63 and 3.78 at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF in both the experimental year and pooled and the lowest recorded in the control plot (2.53, 2.33 and 2.43). [28], [3] also reported significant increase in the no. of seeds pod^{-1} with Zn application @ 20 kg ha^{-1}. This increased in the no. of seeds $pods^{-1}$ might be due to the role of zinc in seed formation [20]. The seed and stover yield of soybean were increased significantly with zinc fertilization as shown in Table 3. The maximum seed and stover yield in both the experimental year and pooled were 1814.50, 1837.90, 1826.20 and 1406.40, 1424.20, 1415.30 kg ha^{-1} @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF. The lowest seed and stover yield were recorded in the control plot. [21] also reported significant increase in the seed and stover yield of lentil as compared to control. This increased in the seed yield may be due to the influenced of zinc on the synthesis of IAA which indirectly enhanced the growth, development and uptake of nutrient in cowpea [38].

[18] also reported significant increase in grain and stover yield in rice – wheat cropping system due to sufficient zinc fertilization leading to increase in protoplasmic constituents, accelerates cell division and elongation, photosynthesis, respiration, biochemical and physiological activities. The protein content and protein yield were also significantly increased @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF in soybean during both the experimental years and pooled as shown in table 4. The highest protein content and yield observed were 39.38, 38.69, 39.04 % and 714.55, 711.08, 712.82 kg ha^{-1} during 2019, 2020 and pooled respectively as compared to control. [17], [30] also observed increased in protein yield and protein content in groundnut and chick pea with increasing zinc levels. [22] observed an increased in the protein content in soybean with zinc application due to its involvement in the N metabolism which increases the amino acid accumulation and increases the rate of protein synthesis in seeds. The oil content and oil yield were significant increased with increasing levels of Zn at various Zn sources (Table 5). The maximum oil content and oil yield in soybean recorded at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF were 23.96, 23.79 and 23.88 % and 434.75, 437.24 and 436.00 kg ha^{-1} in all the experimental years and pooled as compared to control. This increased in the oil content may be due to the improvement of lipid membranes in the presence of zinc [7]. Zinc fertilization also increases the mass weight of plants and thereby increases carbohydrate production and oil content in seeds of canola [19]. [2] also reported significant increase in the oil yield of soybean with increasing levels of Zn.

In this study, the fatty acid composition in soybean was found to be significant at varying sources and levels of Zn application during 2019, 2020 and pooled respectively (Table 5). The maximum value of palmitic acid was reported with the application of 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF viz., 12.93, 12.84 and 12.89 % over control during both the years and pooled. The maximum stearic acid content was recorded at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF viz., 3.89, 3.76 and 3.83% and the lowest was recorded at control in both the years and pooled. Zinc fertilization @ 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF recorded the maximum value of oleic acid in both the years and pooled respectively and the values were 34.45, 34.42 and 34.44 %. The lowest was recorded at control. The maximum linoleic and linolenic acid were observed at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF and the recorded values were 48.04, 48.64, 48.34 % and 4.46, 4.56, 4.51 % in both the experimental years and pooled respectively. The lowest was recorded at control and [1] also found significant increase in oleic acid content with Zn fertilization. The increased in the fatty acid composition with Zn fertilization was also reported by [26] in sunflower crop. Differences in composition of fatty acid in soybean seed oil can be due to its use of different zinc fertilizer inputs [11]. The soybean oil contains more than 50% polyunsaturated fatty acid and the total unsaturated values were ranged from 76.04 to 87.29 %. Similar results were also reported by [29] and [12].

The fertility of the soil after harvest was observed to be significantly increased with various sources and levels of zinc except P (Table 6). The maximum soil available N P K & Zn data recorded during the experimental years and pooled were 345.0, 357.90, 351.45 N, 14.34, 14.44 and 14.39 P, 251.10, 258.15 and 254.63 K kg ha^{-1} and 0.39, 0.35 and 0.35 mg kg^{-1} at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF. The lowest was reported in control. [4] observed significant increase in the soil available N, K and Zn status with the increasing levels of Zn upto 6.0 kg ha^{-1}. [14] also observed that the soil available N, K, Zn increased with the increasing levels of Zn but P in the soil decreased with the increasing levels of Zn. This might be due to the antagonistic effect of Zn and P where higher uptake of Zn may depress the P uptake. Higher transport of Zn from roots to shoot via xylem may also hinder the P translocation from roots to shoots [27].

3. CONCLUSION

From the research conducted, it was observed that zinc fertilization at 5 kg $ZnSO_4$ H_2O ha^{-1} + RDF was found to be optimum among the other zinc sources applied in soybean to enhance the yield, yield attributes and quality aspects under the fine typic Kanhapludalf soil in Nagaland.

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Table 1: Influence of zinc sources on growth and nodulation of soybean

Treatments	Plant height (cm) at maturity			No. of nodules at maturity			Fresh weight of nodules (g) at maturity			Dry weight of nodules (g) at maturity		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	pooled
T_1- 0 (Control)	33.23	33.56	33.40	32.30	29.60	30.95	0.18	0.18	0.18	0.06	0.05	0.05
T_2-RDF + 1Kg $ZnSO_4\ 7H_2O$ ha^{-1}	33.79	33.90	33.85	29.30	38.10	33.70	0.19	0.20	0.20	0.05	0.04	0.05
T_3-RDF + 1 Kg $ZnSO_4\ H_2O$ ha^{-1}	34.13	34.38	34.26	26.00	32.80	29.40	0.24	0.24	0.24	0.06	0.04	0.05
T_4- RDF + 1Kg Zn-EDTA ha^{-1}	34.69	34.60	34.64	30.30	28.70	29.50	0.30	0.31	0.31	0.09	0.07	0.08
T_5-RDF + 2.5 Kg $ZnSO_4\ 7H_2O$ ha^{-1}	34.58	33.76	34.17	38.10	29.90	34.00	0.26	0.28	0.27	0.10	0.06	0.08
T_6-RDF + 2.5Kg $ZnSO_4\ H_2O$ ha^{-1}	34.90	35.00	34.95	32.40	40.60	36.50	0.31	0.29	0.30	0.12	0.11	0.11
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	35.39	34.90	35.15	36.70	36.67	36.69	0.33	0.28	0.31	0.11	0.06	0.09
T_8-RDF + 5Kg $ZnSO_4\ 7H_2O$ ha^{-1}	35.99	35.22	35.61	41.30	40.20	40.75	0.34	0.32	0.33	0.12	0.11	0.12
T_9-RDF + 5Kg $ZnSO_4\ H_2O$ ha^{-1}	36.87	36.91	36.89	46.70	45.10	45.9	0.36	0.37	0.37	0.13	0.12	0.13
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	35.85	35.17	35.78	40.00	37.20	38.60	0.30	0.27	0.29	0.10	0.08	0.09
T_{11}-300ml ha^{-1} liquid ZnO	35.40	35.15	35.28	25.60	30.80	28.20	0.26	0.25	0.26	0.08	0.09	0.09
T_{12}-600ml ha^{-1} liquid ZnO	35.10	35.12	35.11	24.10	28.90	26.50	0.25	0.24	0.25	0.06	0.05	0.05
T_{13}-900 ml ha^{-1} liquid ZnO	35.16	35.09	35.13	26.40	29.70	30.05	0.24	0.22	0.23	0.05	0.04	0.05
SEm±	0.01	0.01	0.01	0.29	0.34	0.22	0.01	0.01	0.01	0.06	0.04	0.05
C.D at 5%	0.04	0.03	0.03	0.83	0.98	0.63	0.02	0.04	0.02	0.09	0.07	0.08

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

Table 2: Effect of the sources and levels of zinc on the yield attributes of soybean

Treatments	No. of pods $plant^{-1}$			No. of seeds $pods^{-1}$		
	2019	2020	Pooled	2019	2020	Pooled
T_1- 0 (Control)	76.30	63.30	68.80	2.53	2.33	2.43
T_2-RDF + 1Kg $ZnSO_4\ 7H_2O$ ha^{-1}	80.43	83.80	81.95	2.53	2.87	2.70
T_3-RDF + 1 Kg $ZnSO_4\ H_2O$ ha^{-1}	84.83	84.70	78.00	2.67	3.00	2.83
T_4- RDF + 1Kg Zn-EDTA ha^{-1}	88.50	82.30	85.4	3.07	2.67	2.87
T_5-RDF + 2.5 Kg $ZnSO_4\ 7H_2O$ ha^{-1}	89.30	89.30	88.30	2.30	3.23	2.80
T_6-RDF + 2.5Kg $ZnSO_4\ H_2O$ ha^{-1}	81.57	87.00	84.29	2.67	3.00	2.84
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	84.43	88.70	86.57	2.53	2.33	2.88
T_8-RDF + 5Kg $ZnSO_4\ 7H_2O$ ha^{-1}	94.53	96.30	95.42	3.30	3.33	3.32
T_9-RDF + 5Kg $ZnSO_4\ H_2O$ ha^{-1}	104.30	107.20	105.75	3.93	3.63	3.78
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	94.47	91.00	92.74	3.23	3.30	3.27
T_{11}-300ml ha^{-1} liquid ZnO	64.63	63.70	64.17	2.10	2.00	2.05
T_{12}-600ml ha^{-1} liquid ZnO	66.70	65.10	65.90	2.03	2.67	2.35
T_{13}-900 ml ha^{-1} liquid ZnO	64.70	69.00	66.85	2.67	2.07	2.37
SEm±	0.75	0.43	0.43	0.36	0.34	0.25
C.D at 5%	2.13	1.21	1.24	1.03	0.96	0.69

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

Table 3: Effect of the sources and levels of zinc on seed and stover yield of soybean

Treatments	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	Pooled
T_1- 0 (Control)	1406.40	1424.20	1415.30	1687.60	1663.80	1675.70
T_2-RDF + 1Kg $ZnSO_4$ $7H_2O$ ha^{-1}	1496.70	1493.60	1495.15	1778.90	1753.70	1766.30
T_3-RDF + 1 Kg $ZnSO_4$ H_2O ha^{-1}	1529.90	1541.70	1535.80	1793.70	1799.30	1796.50
T_4- RDF + 1Kg Zn-EDTA ha^{-1}	1586.60	1599.10	1592.85	1930.40	1989.30	1959.85
T_5-RDF + 2.5 Kg $ZnSO_4$ $7H_2O$ ha^{-1}	1617.00	1630.40	1623.70	1998.10	2113.70	2055.90
T_6-RDF + 2.5Kg $ZnSO_4$ H_2O ha^{-1}	1706.30	1739.40	1722.85	2096.90	2122.30	2109.60
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	1693.40	1718.90	1706.15	2019.30	2131.90	2075.60
T_8-RDF + 5Kg $ZnSO_4$ $7H_2O$ ha^{-1}	1767.80	1749.50	1758.65	2135.20	2197.90	2166.55
T_9-RDF + 5Kg $ZnSO_4$ H_2O ha^{-1}	1814.50	1837.90	1826.20	2198.10	2226.30	2212.20
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	1649.80	1706.30	1678.05	2010.60	2088.50	2049.55
T_{11}-300ml ha^{-1} liquid ZnO	1590.90	1585.90	1588.40	1976.60	1968.70	1972.65
T_{12}-600ml ha^{-1} liquid ZnO	1535.10	1550.10	1542.60	1816.10	1843.90	1830.00
T_{13}-900 ml ha^{-1} liquid ZnO	1558.30	1526.60	1542.45	1869.40	1828.90	1849.15
SEm±	0.13	0.02	0.07	0.02	5.87	2.94
C.D at 5%	0.37	0.05	0.19	0.05	16.80	8.27

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

Table 4: Effect of the sources and levels of zinc on protein and oil content in soybean

Treatments	Protein content (%)			Protein yield (kg ha^{-1})			Oil content (%)			Oil yield (kg ha^{-1})		
	2019	2020	Pooled	2019	2020	pooled	2019	2020	Pooled	2019	2020	Pooled
T_1- 0 (Control)	33.50	34.38	33.94	471.14	489.64	480.39	19.24	19.02	19.13	270.59	270.88	270.74
T2-RDF + 1Kg ZnSO4 7H2O ha-1	36.69	35.56	36.13	549.13	531.12	540.13	20.96	20.15	20.56	313.70	300.96	307.33
T_3-RDF + 1 Kg $ZnSO_4$ H_2O ha^{-1}	36.56	35.94	36.25	559.33	556.00	557.67	21.83	20.82	21.33	333.98	320.98	327.48
T4- RDF + 1Kg Zn-EDTA ha-1	36.31	36.25	36.28	576.09	579.67	577.88	22.14	21.04	21.59	351.27	336.45	343.86
T_5-RDF + 2.5 Kg $ZnSO_4$ $7H_2O$ ha^{-1}	36.69	35.31	36.00	593.28	575.69	584.49	21.31	21.19	21.55	344.58	345.48	345.03
T_6-RDF + 2.5Kg $ZnSO_4$ H_2O ha^{-1}	36.25	35.50	35.88	618.53	617.49	618.01	22.39	21.28	21.84	382.04	368.58	375.31
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	35.94	35.19	35.57	608.61	604.88	606.75	22.80	20.63	21.72	386.10	354.61	370.36
T_8-RDF + 5Kg $ZnSO_4$ $7H_2O$ ha^{-1}	37.69	36.75	37.22	666.28	642.94	654.61	23.84	22.56	23.20	421.44	394.69	408.07
T_9-RDF + 5Kg $ZnSO_4$ H_2O ha^{-1}	39.38	38.69	39.04	714.55	711.08	712.82	23.96	23.79	23.88	434.75	437.24	436.00
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	37.56	36.69	37.13	619.66	626.04	622.85	22.35	21.59	21.97	368.73	368.39	368.56
T_{11}-300ml ha^{-1} liquid ZnO	35.25	35.59	35.42	560.79	564.42	562.61	20.12	20.52	20.32	320.09	325.43	322.76
T_{12}-600ml ha^{-1} liquid ZnO	35.44	34.88	35.16	544.04	540.67	542.36	19.49	20.57	20.03	299.19	318.86	309.03
T_{13}-900 ml ha^{-1} liquid ZnO	34.88	34.49	34.69	543.54	526.52	535.03	19.97	19.77	19.87	311.19	301.81	306.50
SEm±	0.01	0.01	0.01	0.01	0.25	0.13	0.22	0.02	0.11	0.01	0.01	0.01
C.D at 5%	0.04	0.04	0.03	0.03	0.72	0.35	0.64	0.05	0.35	0.03	0.03	0.02

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

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Table 5: Effect of the sources and levels of zinc on fatty acids content in soybean

Treatments	Palmitic acid %			Stearic acid %			Oleic acid %			Linoleic acid %			Linolenic acid %			Unsaturation (%)
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	
T_1- 0 (Control)	11.36	11.04	11.20	2.94	2.61	2.78	29.56	29.25	29.41	41.88	44.05	42.97	3.26	4.08	3.67	76.04
T_2-RDF + 1Kg $ZnSO_4$ $7H_2O$ ha^{-1}	11.64	12.01	11.83	3.56	3.30	3.43	33.42	32.79	33.11	47.12	47.34	47.23	4.65	4.65	4.65	84.99
T_3-RDF + 1 Kg $ZnSO_4$ H_2O ha^{-1}	11.89	11.67	11.78	3.54	3.25	3.40	33.36	32.64	33.00	47.06	47.05	47.06	4.52	4.52	4.52	84.58
T_4- RDF + 1Kg Zn-EDTA ha^{-1}	12.38	12.45	12.42	3.46	3.67	3.57	34.01	33.34	33.68	46.05	45.72	45.89	4.37	4.45	4.41	83.98
T_5-RDF + 2.5 Kg $ZnSO_4$ $7H_2O$ ha^{-1}	11.86	11.56	11.71	3.64	3.33	3.49	33.42	33.08	33.25	46.12	46.11	46.12	4.91	4.68	4.80	84.17
T_6-RDF + 2.5Kg $ZnSO_4$ H_2O ha^{-1}	11.64	11.72	11.68	3.07	3.06	3.07	32.36	32.13	32.25	48.24	48.25	48.25	4.42	4.11	4.27	84.77
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	12.66	11.99	12.33	3.28	2.80	3.04	33.68	33.66	33.67	44.42	44.65	44.54	4.74	4.86	4.80	83.79
T_8-RDF + 5Kg $ZnSO_4$ $7H_2O$ ha^{-1}	12.90	12.50	12.70	3.83	3.70	3.77	34.42	33.78	34.10	45.13	44.80	44.97	4.71	4.71	4.71	83.78
T_9-RDF + 5Kg $ZnSO_4$ H_2O ha^{-1}	12.93	12.84	12.89	3.89	3.76	3.83	34.45	34.42	34.44	48.04	48.64	48.34	4.46	4.56	4.51	87.29
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	12.64	12.33	12.49	3.53	3.39	3.46	31.36	31.05	31.21	44.12	44.41	44.27	4.79	4.79	4.79	82.81
T_{11}-300ml ha^{-1} liquid ZnO	12.60	11.51	12.06	3.67	3.53	3.60	32.60	32.60	32.60	46.23	46.31	46.27	4.38	4.38	4.38	83.25
T_{12}-600ml ha^{-1} liquid ZnO	11.93	11.39	11.66	3.68	3.56	3.62	32.18	31.97	32.08	48.09	47.33	47.71	4.31	4.11	4.21	84.00
T_{13}-900 ml ha^{-1} liquid ZnO	11.75	12.31	12.03	3.69	3.47	3.58	32.42	32.16	32.29	47.33	47.11	47.22	4.61	4.58	4.60	84.11
SEm±	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
C.D at 5%	0.05	0.04	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.03	0.04	0.02	0.02	0.03	0.02	

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

Table 6: Effect of the sources and levels of zinc on soil available NPK&Zn after harvest

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})			Available Zn (mg kg^{-1})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1- 0 (Control)	219.10	231.70	225.40	14.34	14.44	14.39	115.70	129.00	122.38	0.24	0.23	0.23
T_2-RDF + 1Kg $ZnSO_4$ $7H_2O$ ha^{-1}	251.30	274.00	262.65	13.10	13.62	13.36	134.20	154.06	144.13	0.23	0.24	0.24
T_3-RDF + 1 Kg $ZnSO_4$ H_2O ha^{-1}	274.70	269.10	271.90	11.01	12.91	11.96	149.80	135.12	142.46	0.32	0.21	0.22
T_4- RDF + 1Kg Zn-EDTA ha^{-1}	293.00	288.30	290.65	12.17	11.40	11.79	163.20	214.29	188.75	0.29	0.25	0.27
T_5-RDF + 2.5 Kg $ZnSO_4$ $7H_2O$ ha^{-1}	289.90	293.80	291.85	12.97	12.38	12.67	189.90	219.09	204.50	0.26	0.30	0.30
T_6-RDF + 2.5Kg $ZnSO_4$ H_2O ha^{-1}	313.20	330.60	321.90	10.24	12.83	11.54	190.20	225.21	207.71	0.39	0.33	0.33
T_7-RDF + 2.5Kg Zn-EDTA ha^{-1}	337.00	345.50	341.25	12.30	11.47	11.88	194.60	226.17	210.39	0.30	0.29	0.30
T_8-RDF + 5Kg $ZnSO_4$ $7H_2O$ ha^{-1}	342.80	351.20	347.00	11.48	12.46	11.97	240.40	248.24	244.32	0.36	0.34	0.35
T_9-RDF + 5Kg $ZnSO_4$ H_2O ha^{-1}	345.00	357.90	351.45	12.73	11.22	11.98	251.10	258.15	254.63	0.39	0.35	0.35
T_{10}-RDF + 5Kg Zn ha^{-1}EDTA	328.20	348.80	338.50	13.39	12.24	12.82	228.40	223.36	225.88	0.32	0.33	0.33
T_{11}-300ml ha^{-1} liquid ZnO	319.30	316.10	317.70	11.68	11.72	11.70	213.10	201.29	207.20	0.20	0.21	0.21
T_{12}-600ml ha^{-1} liquid ZnO	320.60	314.40	317.50	12.08	11.15	11.62	211.20	201.51	206.36	0.24	0.20	0.22
T_{13}-900 ml ha^{-1} liquid ZnO	309.40	313.00	311.20	11.72	12.06	11.89	216.10	190.40	203.25	0.21	0.21	0.21
SEm±	0.12	0.17	0.10	0.74	0.80	0.55	0.02	0.01	0.01	0.01	0.01	0.01
C.D at 5%	0.36	0.48	0.29	NS	NS	NS	0.05	0.02	0.03	0.03	0.02	0.02

*S- Significant at P= 0.05; NS- Non Significant at P > 0.05

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