

Exploring the Potential of Sulphur Nanoparticles in Soybean (*Glycine max*) Cultivation

ABSTRACT

Background- Nanoparticles treated as “magic bullets” containing nano-fertilizer which will trigger specific cellular organelles in plant to release their contents. Nanoparticle’s behaviour, mobility and their smart delivery system has a strong bearing on the growth and yield of crops.

Study design & Place: A pot study was conducted in CRD at net house of Micronutrient Research Scheme, AAU, Anand during *kharif* season of 2021-22 to study the “Effect of sulphur nanoparticles on growth and yield of soybean

Methodology: A pot study was conducted at net house of Micronutrient Research Scheme, AAU, Anand during *kharif* season of 2021-22 to study the “Effect of sulphur nanoparticles on growth and yield of soybean” at SNPs/kg @ 1 to 8 ppm soil and ES @ 4, 6 & 8 ppm S/kg soil. The pot experiment was laid out in a control randomized block design with four replications comprising of 12 treatments.

Results: Application of 8 ppm SNPs/kg and Elemental sulphur 6 mg/kg soil in soybean resulted in significantly higher grain yield and nutrient content in comparison to control and other treatments. Thus, the study recommended the correct concentration of SNPs (8ppm) ES 6 mg for enhancing soybean production.

Keywords-Elemental Sulphur, Fractionation, Sulphur Nanoparticles, Soil Plant analysis Development

- 1. INTRODUCTION-** Soybean (*Glycine max* L.) is an important leguminous oil seed crop and due to nutritional value, it has been considered as “Protein hope of future”. The Soybean contains 40-45% protein and 18-20% oil. The USA, Brazil and Argentina are major producers of soybean. In India, soybean is one of the fastest growing crops. Soybean is high in protein and a decent source of both carbohydrate and fat and a rich source of various vitamins, minerals, and beneficial plant compounds, such as isoflavones. In India the total area under soybean cultivation is 11.2 million ha with the production and the productivity of 10.5 million metric tons and 937 kg ha⁻¹, respectively (Anon., 2020a). Soybean cultivation is limited to Madhya Pradesh, Maharashtra, Gujarat and Rajasthan state of India. In Gujarat, the total area under soybean cultivation is 1.342 million ha with the production and the productivity of 1.241 million metric tons and 673 kg ha⁻¹, respectively

(Anon.,2020b).

Nano-fertilizers could be more soluble or more reactive than bulk fertilizers and they can exactly release their active ingredients in responding to environmental triggers. Nano- fertilizer_have_high surface_area,increased_solubility,small_particle_size_<100nm,controlled release of nutrients due to encapsulation and increased nutrient efficiency (Yuvaraj and Subramanian,2015).Sulphur nanoparticles_has_a_great_potentialas_fertilizer_carrier_to_control release of sulphate by the slow release mechanism. Despite several agronomic strategies tested for improving the use S efficiency, it proved less success due to complex soil environmental_factors.Sulphur_use_efficiency_hardly exceeds_25%(Kyllingsbaekand Hansen, 2007).

Sulphur is an essential macronutrient in plant growth and development. Sulphur_is_now recognized_as_the_fourth_major_plant_nutrient(Tandon *etal.*,2004; Oakleyet *al.*, 2007). Plants take up sulphur in sulphate form. Sulphur is essential element in forming protein, enzymes, vitamins and chlorophyll in plants and metabolites including glutathione, glucosinolate and alliin. Sulphur plays important role in formation of three amino acids (cysteine,cystinine,and methionine),activation_of enzymes,winter_hardiness,and quality_nutrient_in oilseed (Prasad and Shivay, 2017). Sulphur plays key role in protein synthesis, chlorophyll formation and oil synthesis. Cysteine and methionine are the most important sulphur containing amino acids in plants, wherethey both occur as free acids and as building blocks of proteins (Mengel *et al.*, 2001). Besides it is involved in various metabolic and enzymatic process including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation (Rao, 2001). Nano sulphur allows the plants to efficiently utilize nutrient by rapidly reducing the soil reaction (pH) and cause increase in yield and quality. With the intensive cultivation of soybean, the lack of sulphur becomes a limiting factor in the yield of this crop over time. Lastly, it is possible to use the nano sulphur not only as a fertilizer but also for plant protection and plant growth stimulants.

2. **MATERIALSANDMETHODS-** The pot study was conducted at net house of Micronutrient Research Scheme, AAU, Anand during_kharif_season_of_2021-22_to_study_the_Effect_of_sulphur nanoparticles_on_growth_and_yield_content_of_soybean (NRC-37).

2.1_COLLECTION AND PREPARATION OF SOIL SAMPLE -The soil used under study is representative soils of the middle Gujarat region and is_locally known as "Goradu" soil. The texture of the soil is loamy sand and_moisture_retentive,belongs_to_the_soil_order Inceptisols(*TypicUstochrept*).It responds well to manuring and is suitable to variety of crop of tropical region. The_texture_of_the_soil_is_loamy_sand_and_the_soil_used_forth_eexperiment was neutral in reaction, medium in available P_2O_5 , available K_2O , DTPA-Zn was sufficient and_deficient_in_available sulphur. The weather parameters *viz.*, temperature, average relative humidity, wind velocity and bright sunshine hours observed during the experiment period. The seasonable rainfall was received

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during study period. In general, the weather conditions were found favourable for normal growth of soybean crop.

2.2 POT FILLING -The 15 kg capacity earthen pots were selected for the pot study. At the time of pot filling, the drainage hole covered with broken pot piece to ensure proper drainage and to avoid water logging. Fifteen kilograms of soil was taken in each pot. The recommended dose of N and P₂O₅ were added through urea and potassium dihydrogen phosphate. Fertilizer applied on basis of the weight of hectare furrow slice. The sulphur nanoparticles was applied in soil as basal application before sowing. After proper filling soil in the pots, initially ten healthy seeds of soybean were sown into each pot at proper depth. Thinning was done after germination and finally 2 plants were kept for study. Pots were regularly watered and weed free condition maintained up to maturity stage for well vegetative growth and development of crop. The observations like plant height at 30 & 60 DAS and at harvest, chlorophyll content at 45 DAS & no. of pods per plant were taken in accordance with the crop growth in pots at maturity stage, seed and stover yield were also recorded from each pot.

The treatments were comprised of T₁ (control only NPK), T₂ (T₁ + sulphur nanoparticles @ 1mg S/kg soil), T₃ (T₁ + sulphur nanoparticles @ 2 mg S/kg soil), T₄ (T₁ + sulphur nanoparticles @ 3 mg S/kg soil), T₅ (T₁ + sulphur nanoparticles @ 4 mg S/kg soil), T₆ (T₁ + sulphur nanoparticles @ 5 mg S/kg soil), T₇ (T₁ + sulphur nanoparticles @ 6 mg S/kg soil), T₈ (T₁ + sulphur nanoparticles @ 7 mg S/kg soil), T₉ (T₁ + sulphur nanoparticles @ 8 mg S/kg soil), T₁₀ (T₁ + elemental sulphur @ 4 mg S/kg soil), T₁₁ (T₁ + elemental sulphur @ 6 mg S/kg soil) and T₁₂ (T₁ + elemental sulphur @ 8 mg S/kg soil).

3. RESULTS AND DISCUSSION

3.1 EFFECT OF DIFFERENT LEVELS OF SULPHUR NANO PARTICLES ON GROWTH PARAMETERS OF SOYBEAN

Table1-Effect of different levels of sulphur nanoparticles on periodical plant height, Leaf chlorophyll SPAD value and pod per plant of soybean

Tr. No.	Plant height (cm)			SPAD value	No. of pod/plant
	30 DAS	60 DAS	At harvest		
T ₁ -Control(NPKonly)	39.98	93.70	108.45	18.25	20.75
T ₂ -RDF + SNPs @ 1 mg S/kgsoil	41.27	96.63	113.13	19.55	22.25
T ₃ -RDF+SNPs @2mg S/kgsoil	41.95	96.88	115.63	20.93	23.25
T ₄ -RDF+SNPs@3mg S/kgsoil	45.64	97.35	116.20	21.13	23.25
T ₅ -RDF+ SNPs@4mg S/kgsoil	45.93	99.28	117.43	21.48	24.00
T ₆ -RDF+SNPs @5mg S/kgsoil	46.16	97.95	117.63	21.86	24.75
T ₇ -RDF+SNPs @6mg S/kgsoil	46.60	97.55	118.33	22.01	25.00
T ₈ -RDF+SNPs @7mg S/kgsoil	46.95	98.40	119.60	22.33	25.00
T ₉ -RDF+SNPs@8mg S/kgsoil	47.78	99.58	120.43	22.73	26.25
T ₁₀ -RDF+ES @4mg S/kgsoil	41.13	97.38	116.48	22.03	21.50
T ₁₁ -RDF+ES @6mg S/kgsoil	43.72	97.28	117.15	21.05	22.25
T ₁₂ -RDF+ES @8mg S/kgsoil	42.98	95.38	115.33	19.34	21.00
SEm±	0.99	0.95	0.65	0.38	0.50
CD at 5%	2.84	2.72	1.87	1.09	1.44
CV (%)	4.48	1.95	1.12	1.46	4.31

Regarding plant height at harvest, all treatments showed significant effect on plant height over control (Table.1). Plant height was recorded higher at 30, 60 and at harvest 90-DAS (47.78cm) (99.58cm) (120.43cm) respectively under T₉ which was statistically at par with T₈ only. The improvement in plant height under treatments T₉ and T₈ were to the tune of 30.37 and 26.67 per cent, respectively, over control (108.45 cm). These results were in a line with those of Thirunavukkarasu & Subramanian (2015). The higher chlorophyll content (22.73) at 45 DAS was observed under T₉ (8mgSNPs/kgsoil) which was statistically at par with treatments T₅, T₆, T₇, T₈ & T₁₀ (21.48, 21.86, 22.01, 22.33, 22.03), respectively. The increase in chlorophyll content under treatments T₉ was to tune of 21.73 per cent over control.



T₉-SNPs @ 8 mg S/kg soil T₁₂-ES @ 68 mg S/kg soil T₁-Control

Fig. 1 Effect of Sulphur Nanoparticles and ES on growth of Soybean

The beneficial effect of treatments were observed on number of effective pods per plant as compared to control, where insignificantly higher number of pods per plant (26.25) found with T₉(8mgSNPs/kgsoil)over the other treatments but,it was statistically at par with T₇ (6 mg SNPs /kg soil) and T₈ (7 mg SNPs /kg soil). The increased in pods might be due to increased sulphur uptake as the result of enhanced availability of essential nutrients in soil due to the application of SMNZ based sulphur fertilizer. This might be due to more accumulation of amino acids and amide substances and their translocation to reproductive organs which influenced growth and yield due to application of sulphur (Dongarkaret *al.*, 2005).

3.2 EFFECT OF DIFFERENT LEVELS OF SULPHUR NANO PARTICLES ON YIELD OF SOYBEAN

Table2-Effect of sulphur nanoparticles on seed, stover and shell yield of soybean

Tr. No.	Yield (g/pot)			
	No.of pod	Seed	Stover	Shell
T ₁ -Control(NPKonly)	20.75	9.57	7.55	1.68
T ₂ -RDF + SNPs @ 1 mg S/kgsoil	22.25	9.65	7.77	1.90
T ₃ -RDF+SNPs @2mg S/kgsoil	23.25	9.68	8.21	2.08
T ₄ -RDF+SNPs@3mg S/kgsoil	23.25	9.88	9.04	2.10
T ₅ -RDF+ SNPs@4mg S/kgsoil	24.00	10.17	9.04	2.10
T ₆ -RDF+SNPs @5mg S/kgsoil	24.75	10.63	9.38	2.13
T ₇ -RDF+SNPs @6mg S/kgsoil	25.00	10.80	9.90	2.13

T ₈ -RDF+SNPs @ 7mg S/kgsoil	25.00	11.15	10.05	2.18
T ₉ -RDF+SNPs@8mg S/kgsoil	26.25	11.25	10.38	2.50
T ₁₀ -RDF+ES @4mg S/kgsoil	21.50	10.63	9.15	2.00
T ₁₁ -RDF+ES @6mg S/kgsoil	22.25	10.40	8.81	1.85
T ₁₂ -RDF+ES @8mg S/kgsoil	21.00	9.83	7.76	1.75
SEm±	0.50	0.19	0.29	0.20
CD at 5%	1.44	0.56	0.82	NS
CV (%)	4.31	3.78	6.44	20.1

The data on seed yield presented in Table -2 revealed that among different treatments, T₉ (8 mg SNPs /kg soil), T₈ (7 mg SNPs /kg soil) and T₇ (6 mg SNPs /kg soil) recorded significantly higher seed yield of soybean over control (9.57 g/pot). The significantly highest seed yield (11.25g/pot) recorded under T₉, which was remained at par with T₈ and T₇ and the percent enhancement in seed yield was to the tune of 17.55 due to T₉ treatment. Among different SNPs treatments, T₉ (8mg SNPs/kgsoil) treatment found comparatively better as compared to T₈ (7 mg SNPs /kg soil). Among different treatments, T₉ (8 mg SNPs /kg soil), T₈ (7 mg SNPs/kg soil) and T₇ (6 mg SNPs /kg soil) significantly increased stover yield over control (7.55g/pot). This significantly higher stover yield (10.38 g/pot) recorded under T₉, which was statistically at par with T₈ & T₇. Among different treatments of nano-particles, 8 mg SNPs /kg soil (T₉) found comparatively better as compared to 7 mg SNPs /kg soil (T₈). The shell yield was non-significantly affected by different treatments over control. The highest shell yield (2.5 g/pot) was recorded under T₉ treatment.

This increase in soybean yield is relevant with its productivity after using nano sulphur as compared to mineral sulphur (control) might be due to that application of nano sulphur resulted in increase in the germination rate, germination percentage, seedling fresh and dry weights and root length were improved under salinity (Ashour *et al.*, 2017). The positive effect of sulphur on seed yield is one of the most widely documented facts across the world (Patel, 2009; Behera *et al.*, 2021). Since the pore diameter of cell walls of root hairs of plants is in the range of 3.5-3.8nm, only nanoparticles or aggregates with diameters less than the cell wall pore diameter can enter the cell wall of undamaged cells (Dietz and Herth, 2011).

The plant growth and yield attributes of soybean like plant height and number of pods per plant significantly ($P=0.05$) increased due to treatment T₉ (RDF+SNPs@8mgS/kg

Soil treatment which was at par with treatments T₄, T₅, T₆, T₇ & T₈; in case of plant height at 30, 60 DAS and at harvest and at par with treatments T₈ & T₇ in case of pods per plant. The leaf chlorophyll content at 45 DAS of soybean was also significantly increased due to T₉ (RDF+SNPs@8mgS/kgsoil) which was at par with T₁₀ RDF+Elemental-S@4mgS/kgsoil. The significantly ($P =$

0.05) highest seed and stover yield of soybean recorded under treatment T₉(RDF+ SNPs @ 8 mg S/kg soil) and was at par with T₇& T₈ in case of seed and stover yield, whereas the application of elemental S @ 4, 6 & 8 mg S / kg soil significantly decreased seed and stover yield of soybean. The shell yield was non-significantly affected by different sulphur application treatments.

4. CONCLUSION- On the basis of results, it can be concluded that the application of sulphur nano-particles @ 8 mg S/kg soil along with RDF (NPK 30:60:00 kg/ha) significantly increased growth and yield attributes of soybean over control (RDF only) and elemental sulphur @ 4, 6 & 8 mg S/kg soil. The sulphur nanoparticles proved better in increasing the growth, yield attributes and yields of as compared to elemental sulphur in loamy sand soil.

RDF- Recommended Dose of Fertilizer
SNPs- Sulphur Nano particles
Es- Elemental Sulphur
SPAD- Soil Plant Analysis Development

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