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Effect of different levels of chemical and nano nitrogenous fertilizers on content and uptake of N, P, K by sorghum crop cv. Gundari

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Abstract
A pot culture experiment was conducted to study the effect of chemical and nano nitrogenous fertilizer on content and uptake of N, P, K by grain and straw of sorghum (*Sorghum bicolor* L.) crop. The investigation was carried out in CRD design three replication with seven different treatments. The treatments included T_1 = Absolute control (No fertilizer), T_2 = Nano polymer, T_3 = RDN dose of sorghum crop through chemical fertilizer, T_4 = $NN_{2.5}$-2.5 times reduction of RDN through nano fertilizer, T_5 = NN_5-5 times reduction of RDN through nano fertilizer, T_6= NN_{10}-10 times reduction of RDN through nano fertilizer, T_7 = RDN through nano fertilizer. The result reported significantly highest contents of major nutrients (N, P and K) and micronutrients (Fe, Mn, Zn and Cu) in grain and straw with nano nitrogenous fertilizer treated soils. The nano nitrogenous fertilizer also significantly increased the uptake of N, P, K, Fe, Mn, Zn and Cu by grain and straw.

Keywords: Nano fertilizer, nano polymer, chemical fertilizer, nanotachnology, recommended dose of nitrogen

Introduction

Sorghum (*Sorghum bicolor* L.) is a warm-season (C_4 photosynthetic pathway), short-day annual grass. It grows best under relatively high temperatures and under sunny conditions. Sorghum as a crop originated as far back as 3,000 years ago (Mir *et al*., 2015) [7]. Sorghum is a drought tolerant and nutritious cereal crop usually cultivated for food, feed and fodder by subsistence farmers in India. Elsewhere in the world, especially in semiarid tropical (SAT) regions, where the production is constrained by low and erratic rainfall and low soil fertility, it is grown and consumed as staple food and is also used in the production of a variety of by-products like alcohol, edible oil, confectionary items and sugar. Sorghum is the fifth most important cereal crop worldwide (Shamme *et al*., 2016) [15]. Nitrogen fertilizer is one of the key drivers producing high yields in modern agriculture, and its use has grown substantially over the past 40 years. Nitrogen fertilizer is a compound that is added to plants to stimulate growth. The nitrogen stimulates chloroplast in plants, which is responsible for photosynthesis. The development of nitrogen fertilizer began in 1905 with German chemist Fritz Haber. Haber discovered a way to fix nitrogen from air. He received a noble prize for his work in 1918. The applied N through fertilizers undergo transformation processes such as biological nitrogen fixation 62-83% (Subba Rao,1988) [16], humus mineralization 1-4%, immobilization 35-53%, nitrification 21% and 50% at acidic and alkaline pH, respectively (Patra *et al*., 2006) [12], denitrification 24-53% and volatilization 1-44% (Parashar *et al*., 1998 and Prasad *et al*., 1999) [13, 11]. These transformation processes make N management very complex and quite difficult to improve the N use efficiency. In order to improve the N use efficiency by crops, several strategies have been suggested in the past few decades. Nano fertilizer technology is designed to deliver nutrients in a regulated pattern in correspondence with the crop demand thereby nutrient use efficiency can be improved without associated ill-effects (Naderi and Shahraki, 2013) [9]. The concept of nanotechnology is attributed to nobel laureate Richard Feymen who gave a very famous visionary speech in 1959 during one of his lectures. He said “there is plenty of room at the bottom”. He is known as father of nanotechnology. The term nanotechnology was coined in 1974 by Norio Taniguchi at the University of Tokyo. The word “Nanotechnology” has originated from a Greek word ‘nanos’ which means “dwarf”. During the 1950s, Arthour von Hippel proposed the term “molecular engineering” and predicted the feasibility of constructing nano molecular devices (Goel, 2015) [2]. Nano-fertilizer technology is designed to deliver nutrients in a regulated pattern in correspondence with the crop demand thereby nutrient use efficiency can be improved without associated ill-effects.

Materials and Method

A pot study was conducted in summer season of 2017 with 7 treatments replicated in thrice under net house condition at Department of Biotechnology, JAU, Junagadh. The experimental soil was *Vertic Haplustepts*, medium black calcareous clayey in nature and slightly alkaline in reaction. Earthen pots having an upper diameter of 30 cm and lower diameter of 15 cm with 25 cm height were used in investigation. The pots were filled with 15 kg of soil. The required quantity of nitrogen was calculated as per treatment of different sources of nitrogen product on the basis of 15 kg bulk of soil and applied as basal dose. The pot culture experiment was conducted with seven levels of nitrogen and two different source of nitrogen (Urea and Nano N Fertilizer) in completely randomized block design. The required quantity of potassium and phosphorus was applied as basal dose through KCl and SSP were also mixed with the soil. The treated soil was filled in polythene lined earthenware pots.

Table 1: Treatment details of nano and chemical fertilizers

S. No.	Treatments	Nitrogen (g per 15 kg soil)	Source
1	T_1	0	No fertilizer
2	T_2	0 g urea in 2.90 liter nano polymer	Nano polymer
3	T_3	3.48	Urea
4	T_4	1.38 g urea in 1.15 liter nano polymer	Nano N fertilizer
5	T_5	0.68 g urea in 0.56 liter nano polymer	Nano N fertilizer
6	T_6	0.34 g urea in 0.28 liter nano polymer	Nano N fertilizer
7	T_7	3.48 g urea in 2.90 liter nano polymer	Nano N fertilizer

Note: SSP (2.51gm) and MOP (0.66gm) was applied as basal dose

Fig 1: Overall view of Pot culture study (Location-Dept. of Biotechnology, JAU, Junagadh)

Result and Discussion

i) Effect of different levels of chemical and nano nitrogenous fertilizers on quality parameters, content and uptake of nitrogen by grain and straw of sorghum crop

The data furnished in Table 1 revealed that the effect of different levels of chemical and nano nitrogenous fertilizers produced significant effect on crude protein content and protein yield. The highest protein content (13.46%) was observed under T_4 (2.5 time reduction of RDN through nano fertilizer) treatment, but it was statistically at par with T_3, T_5 and T_7 treatments. The minimum protein content (8.32%) was observed under control treatment followed by nano polymer (9.52%) treatment in grain of sorghum. Application of nano fertilizer significantly increased the protein content to the extent of 61.81% under T_4 treatment as compared to control. The similar trend was also observed in the case of protein yield. The highest (6.48 g pot^{-1}) protein yield was observed with the application of 2.5 times reduction of recommended dose of nitrogen through nano fertilizer but application of nano fertilizer beyond T_4 level cause depressing effect on protein content of sorghum grain. The findings of Manikandan and Subramanian (2016) [6] and Mala *et al*. (2017) [8] are in supporting the present investigation. Mala *et al*. (2017) [8] concluded that nano slow release fertilizer treatment stimulated germination and biochemical characteristics of *Vigna radiata*. The protein concentrations were found highest with the application of nano fertilizer treated soil as compared with the conventional fertilizer. It might be due to nano fertilizers provide more surface area and more availability of nutrient to the crop plant which help to increase these quality parameters of the plant by enhancing the rate of reaction or synthesis process in the plant system. Nutrient content is a causative factor of the treatment effects on crop yield and quality produce. The result of different levels of chemical and nano nitrogenous fertilizers on nitrogen content in grain and straw of sorghum crop are furnished in Table 1. The data conclusively demonstrate that nitrogen content in grain and straw significantly affected by the application of different levels of chemical and nano nitrogenous fertilizers. The maximum nitrogen content in straw (1.67%) was observed under T_4- (2.5 time reduction of RDN through nano fertilizer) which was stastically at par (1.67%) with T_7 (RDN through nano nitrogenous fertilizer) while, the lowest nitrogen content (1.25%) was observed under control treatment in the soil. Sorghum grain is the major sink of the mineral nutrients. Nitrogen content in grain was significantly affected by the application of different levels of chemical and nano nitrogenous fertilizers. The maximum nitrogen content in grain (2.15%) was obtained with the application of T_4-2.5 time reduction of RDN through nano fertilizer which was found statistically at par (1.98%) with T_7 (RDN through nano fertilizer).The lowest nitrogen content in grain (1.36%) was recorded with the control treatment followed by nano polymer (1.52%). Effect of chemical and nano nitrogenous fertilizers on nitrogen uptake is given in Table 1. The uptake of nitrogen by straw, grain and its total uptake increased remarkably with the different levels of nano and chemical nitrogenous fertilizers. The maximum nitrogen uptake by straw (1.96 g pot^{-1}) was observed under T_4 (2.5 time reduction of RDN through nano fertilizer) followed by T_7 (1.92 g pot^{-1}) and which was found statistically at par with each other. The lowest (0.57 g pot^{-1}) nitrogen uptake was observed under control treatment. Nitrogen uptake by grain is also similar with that of straw. The highest nitrogen uptake (1.10 g pot^{-1}) by grain was recorded with the application of T_4 (2.5 time reduction of RDN through nano fertilizer) and lowest uptake of nitrogen (0.43 g pot^{-1}) was observed under control. The similar trend was also found for total nitrogen uptake. The highest total N uptake by the sorghum crop under different levels of nitrogen application might be due to the congenial growth environment and slow release nature of nano fertilizer for development of sorghum root hairs might have led to enhanced N uptake by the roots of the plant, resulting in enhanced uptake of the nutrient and its concentration in the grain and straw tissues.

Table 2: Effect of different levels of chemical and nano nitrogenous fertilizers on quality parameters, content and uptake of nitrogen by grain and straw of sorghum crop

Treatments	Nitrogen Content (%)		Nitrogen Uptake (g pot^{-1})			Protein (%)	Protein yield (g pot^{-1})
	Grain	Straw	Grain	Straw	Total		
T_1 - Absolute Control	1.36	1.25	0.43	0.57	0.99	8.32	2.68
T_2 - Nano polymer	1.52	1.43	0.54	0.71	1.25	9.52	3.38
T_3 -RDN through chemical fertilizer	1.81	1.50	0.86	1.28	2.13	11.33	5.36
T_4 - $NN_{2.5}$ -2.5 time reduction of RDN through nano fertilizer	2.15	1.67	1.10	1.96	3.06	13.46	6.89
T_5 - NN_5 -5 time reduction of RDN through nano fertilizer	1.76	1.48	0.80	1.51	2.31	11.0	5.01
T_6 - NN_{10} -10 time reduction of RDN through nano fertilizer	1.68	1.46	0.67	1.20	1.88	10.50	4.21
T_7 - RDN through nano fertilizer	1.98	1.66	0.99	1.92	2.91	12.35	6.17
S.Em$\pm$	0.08	0.05	0.04	0.04	0.04	0.53	0.24
C.D. at 5%	0.26	0.15	0.12	0.13	0.13	1.59	0.73
C.V.%	8.32	5.67	8.66	5.55	3.49	8.32	8.66

ii) Effect of different levels of chemical and nano nitrogenous fertilizers on phosphorus content and its uptake by grain and straw of sorghum crop.

The application of 2.5 times reduction of RDN through nano fertilizer produced significantly highest (0.29%) P content in straw but it was statistically at par with T_7 (RDN through nano fertilizer) treatment. The lowest P content (0.20%) was observed under control treatment and it was statistically at par with treatment of T_2 (0.21%). The same trend was also observed in case of P uptake by straw. The maximum P uptake by straw was observed under treatment T_4 (0.32 g pot^{-1}). But it was statistically at par with T_7 (0.31 g pot^{-1}) treatment, While, lowest P uptake by straw was (0.09 g pot^{-1}) recorded under control and it was statistically at par with treatment of T_2 (nano polymer). The results summarized in Table 2 indicated that different levels of chemical and nano nitrogenous fertilizers produced significant effect on P content and uptake by sorghum grain. The significantly highest P content in grain was (0.47%) observed under treatment T_4 (2.5 times reduction of RDN through nano fertilizer) followed by T_5, T_6 and T_7 treatments. The lowest P content (0.31%) was observed under control, but it was statistically at par with the treatment T_2 (0.33%). The effect of different treatments of nitrogen on P content in straw and grain was found significant. The maximum P uptake by grain was observed under treatment of T_4 (0.24 g pot^{-1}). But it was statistically at par with T_7 (0.22 g pot^{-1}) treatment. While, lowest P uptake was (0.10 g pot^{-1}) recorded under control. The similar trend was also observed in case of total phosphorus uptake by sorghum crop. The positive effect of nitrogen on P uptake by grain and straw of sorghum crop could be attributed due to surface coatings of nano materials on fertilizer particles hold the material more strongly due to higher surface area than the conventional fertilizer and thus help in controlled release and reduce the nutrient fixation. These result are in agreement with the earlier work of Zaki (2016) [18], Rana *et al.* (2017) [14], Brohi *et al.* (1997) [1], Shivay and Kumar (2007) [17], Hirzel and Rodríguez (2013) [3], Kumar *et al*. (2014), Irshad *et al*. (2014) [4]. Mala *et al.* (2017) [8] reported that nano fertilizer application significantly increase the P content and uptake over conventional fertilizer. It might be due to nano SRF provides both plant growth promoting rhizobacteria and essential macronutrients. PGPR increased the phosphorus uptake by increasing the number and length of roots, and an increase in roots facilitated the absorption of nutrients from the soil). The results summarized in Table 2 indicated that different levels of chemical and nano nitrogenous fertilizers produced significant effect on P content and uptake by sorghum grain. Significantly the highest P content in grain (0.47%) was observed under application of 2.5 times reduction of RDN through nano fertilizer (T_4) treatment followed by T_5, T_6 and T_7 treatments. Out of these treatment of T_7 (0.45%) was remain statistically at par with each other. The lowest P content was (0.31%) observed under control, but it was statistically at par with the treatment of T_2 (0.33%).The effect of different treatments of nitrogen on P content in straw and grain was found significant. The maximum P uptake by grain (0.24 g pot^{-1}) was observed under treatment of T_4. But it was statistically at par with T_7 (0.22 g pot^{-1}) treatment, While, lowest P uptake was (0.10 g pot^{-1}) recorded under control.

Table 3: Effect of different levels of chemical and nano nitrogenous fertilizers on P content and its uptake by grain and straw of sorghum crop

Treatments	Phosphorus content (%)		Phosphorus uptake (g pot^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1 - Absolute Control	0.31	0.20	0.10	0.09	0.19
T_2 - Nano polymer	0.33	0.21	0.12	0.10	0.22
T_3 -RDN through chemical fertilizer	0.41	0.25	0.20	0.24	0.44
T_4 - $NN_{2.5}$ -2.5 time reduction of RDN through nano fertilizer	0.47	0.29	0.24	0.32	0.56
T_5 - NN_5 -5 time reduction of RDN through nano fertilizer	0.39	0.24	0.18	0.21	0.38
T_6 - NN_{10} -10 time reduction of RDN through nano fertilizer	0.35	0.22	0.14	0.18	0.32
T_7 - RDN through nano fertilizer	0.45	0.28	0.22	0.31	0.53
S.Em$\pm$	0.02	0.01	0.01	0.01	0.01
C.D. at 5%	0.05	0.04	0.02	0.03	0.04
C.V.%	7.83	8.66	7.36	7.92	5.87

iii) Effect of different levels of chemical and nano nitrogenous fertilizers on potassium content and its uptake by grain and straw of sorghum crop.

The application of different levels of chemical and nano nitrogenous fertilizers produced significant effect on potassium content and its uptake by straw. The application of nitrogen significantly increased the potassium content in straw from T_1 to T_4 (1.23 to 1.47%), beyond this levels, it was significantly decreased under T_5 and T_6 treatments. The maximum K content (1.47%) was observed under T_4 (2.5 times reduction of RDN through nano fertilizer). But it was statistically at par with T_7 (RDN through nano fertilizer). The lowest K content in straw (1.23%) was recorded under treatment T_1 (control) and it was statistically at par with the treatment T_2 (1.27%). The treatment T_3 (RDN through chemical fertilizer) produced significantly higher K content (1.34%) followed by T_5 (1.33%) and T_6 (1.32%) treatments but lower than T_4 (1.47%) and T_7 (1.43%) treatments. The same trend was also observed in case of K uptake by straw. The maximum K uptake by straw was observed under treatment of T_4 (1.72 g pot^{-1}). But it was statistically at par with T_7 (1.66 g pot^{-1}) treatment, while, the lowest K uptake was recorded under treatment T_1 (0.56 g pot^{-1}). The application of 2.5 times reduction of RDN through nano fertilizer produced significantly the highest (1.17%) K content in grain followed by T_5, T_6 and T_7 treatments, out of these T_7 (1.15%) treatment remained statistically at par with each other. The lowest K content was observed under control (0.8%)) treatment but it was statistically at par with treatment T_2 (0.97%). The same trend was also observed in case of K uptake by grain. The effect of different levels of nitrogenous fertilizer on K content and uptake by grain was found significant. The maximum K uptake by grain was observed under the treatment T_4 (0.60 g pot^{-1}). But it was statistically at par with T_7 (0.57 g pot^{-1}) treatment, While, lowest K uptake was recorded under control (0.25 g pot^{-1}) treatment. The similar trend was also observed in case of total K uptake by sorghum crop. The potassium content and its uptake by straw and grain were observed higher with nano nitrogenous fertilizer than the conventional chemical fertilizer. This might be due to nano structured formulation control the release speed of nutrients to match the uptake pattern of crop. Nano sized formulation of mineral nutrient may improve solubility and dispersion of insoluble nutrients in soil, reduce nutrient losses, fixation and increase the bioavailability leads to increased potash use efficiency.

Table 4: Effect of different levels of chemical and nano nitrogenous fertilizers on K content and its uptake by grain and straw of sorghum crop

Treatments	Potassium content (%)		Potassium uptake (g pot^{-1})		
	Grain	Straw	Grain	Straw	Total
T_1 - Absolute Control	0.80	1.23	0.25	0.56	0.81
T_2 - Nano polymer	0.97	1.27	0.35	0.63	0.98
T_3 -RDN through chemical fertilizer	1.07	1.34	0.51	1.37	1.88
T_4 - $NN_{2.5}$ -2.5 time reduction of RDN through nano fertilizer	1.17	1.47	0.60	1.72	2.32
T_5 - NN_5 -5 time reduction of RDN through nano fertilizer	1.04	1.33	0.47	1.13	1.61
T_6 - NN_{10} -10 time reduction of RDN through nano fertilizer	1.01	1.32	0.41	1.08	1.49
T_7 - RDN through nano fertilizer	1.15	1.43	0.57	1.66	2.30
S.Em$\pm$	0.03	0.04	0.01	0.03	0.03
C.D. at 5%	0.10	0.12	0.03	0.08	0.10
C.V.%	5.38	5.02	4.19	4.05	3.37

Conclusion

Based on the results summarized above, it can be concluded that the application of RDN through nano fertilizer significantly improved the quality parameters like crude protein content in grain of sorghum crop. The nano nitrogenous fertilizer also significantly increased the content and uptake of N, P, K by grain and straw of sorghum crop.

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