Mysore J. Agric. Sci., 58 (4) : 312-319 (2024)

Influence of Nano-Urea on Productivity and Quality of Fodder Oat (*Avena sativa* L.) in Southern Dry Zone of Karnataka

B. G. Shekara, N. M. Chikkarugi and N. Rani
AICRP on Forage Crops and Utilization, Zonal Agricultural Research Station, V.C. Farm, Mandya - 571 405
e-Mail : bgshekar66@gmail.com

Authors Contribution

B. G. Shekara :
Selection of research Problems, plan of work, study design & it's execution, analysis and interpretation of data;

N. M. Chikkarugi & N. Rani :
Investigation, data collection, compilation, statistical analysis and draft preparation

Corresponding Author :
B. G. Shekara

Received : July 2024
Accepted : August 2024

Abstract

The field experiment was conducted at Zonal Agricultural Research Station, Vishweshwaraiah Canal farm, Mandya during *rabi* 2022 & 2023 with an objective of identifying optimum concentrations of Nano urea for obtaining maximum growth, yield and quality in fodder oat under irrigated situation. The experiment consisted of ten treatments, which was laid out in randomized block design with three replications. The treatments included were T_1: Control (without N, only P & K), T_2: 100 per cent recommended dose of fertilizers (100:40:30 NPK kg/ha- 50% N as basal +25% N at 20 DAS + 25% N at 40 DAS), T_3: 75 per cent recommended dose of N + nano urea @ 0.2 per cent spray twice @ 20 & 40 DAS, T_4: 50 per cent recommended dose of N + nano urea @ 0.2 per cent of spray applied twice at 20 & 40 DAS, T_5: 75 per cent recommended dose of N + nano urea @ 0.4 per cent foliar spray applied twice at 20 & 40 DAS, T_6: 50 per cent recommended dose of N + nano urea @ 0.4 per cent @ 20 & 40 DAS, T_7: 75 per cent recommended dose of N + nano urea @ 0.6% @ 20 & 40 DAS, T_8: 50 per cent recommended dose of N + nano urea @ 0.6 per cent of spray @ 20 & 40 DAS, T_9: 75 per cent recommended dose of N + normal urea (2% spray) twice @ 20 & 40 DAS, T_{10}: 50 per cent recommended dose of N + normal urea (2% spray) twice @ 20 & 40 DAS. The pooled data revealed that, application of 100 per cent recommended dose of nitrogen recorded significantly higher plant height (148.8 cm), leaf stem ratio (0.52), green forage (338.7 q ha^{-1}), dry matter (77.5 q ha^{-1}) and crude protein yield (3.59 q ha^{-1}). Similarly, higher gross returns, net returns and benefit cost ratio was also recorded with application of 100 per cent recommended dose of fertilizer (76214 Rs. ha^{-1}, 49950 Rs. ha^{-1} and 2.90, respectively).

Keywords : Fodder oat, Nano urea, Green fodder yield, Dry matter yield, Crude protein yield

Oat (*Avena sativa* L.) is a winter season fodder crop which can be grown in areas with limited irrigation facilities. It is short duration and known to produce high green biomass with rich nutritive forages (Shekara *et al*., 2019). There is a possibility of utilizing the re-growth and its yield potential both for forage and seed production production making it a dual purpose crop. Apart from development of high yielding varieties, adequate nutrition plays a major role in getting higher biomass and quality.

The majority of nano-fertilizers are either synthetic or altered versions of conventional fertilizers, raw fertilizer components or botanical, microbial or animal extracts (Husen and Iqbal, 2019). Nano fertilizers slowly release nutrients throughout the growth period of the crop, allowing plants to absorb nutrients efficiently without experiencing losses like leaching, volatilization, fixation etc. (Guru *et al.,* 2015). Plants can absorb nano fertilizers easily due to their high surface area to volume ratio

(Al-Juthery and Saadoun., 2018). Compared to conventional fertilizer application, nano fertilizers reduce nutrient loss, resulting in 20-30 per cent higher use efficiency (Kumar *et al.,* 2020a and Kumar *et al.,* 2020b). Nano particles or nano encapsulated nutrients have the properties to release nutrients effectively on demand that regulate plant growth and enhance activity (Derosa *et al.,* 2010). Foliar application of nano fertilizers might boost nutrient production and improve plant nutrition when compared to regular fertilizers. The usage of nano fertilizers extends the time and rate of elements released in the plant system, allowing it to match plant nutritional requirements (Kumar *et al.,* 2021). The plant can absorb the maximum amount of nutrients resulting in an increase in crop yield. Keeping these things in view, the present investigation was undertaken to know the different concentration of nano urea on growth, green forage yield and quality in fodder oat.

Material and Methods

The present investigation was carried out at Zonal Agricultural Research Station, Vishweshwaraiah Canal Farm, Mandya, during *rabi* 2022 & 2023 with an objective of identifying optimum concentrations of Nano urea on growth, yield and quality of fodder oat under irrigated situation. The experimental site is situated in the Southern Dry Zone (ACZ-VI) in Karnataka and is 695 meters above mean sea level. It is positioned between 12° 45' and 13° 57' North latitude and 76° 45' and 78° 24' East longitude. The soil is sandy loam in texture at the experimental location and has a neutral soil reaction of 7.13, low organic carbon (0.43%), medium levels of accessible phosphorus (46.3 kg/ha), potassium (159.0 kg/ha) and low levels in available nitrogen (243.0 kg/ha).

The ten treatments combinations, *viz.,* T_1: Control (without N, only P & K), T_2: recommended dose of fertilizers (100:40:30 NPK kg/ha- 50% N as Basal +25% N at 25 DAS + 25% 45 DAS, T_3: 75% recommended dose of N + Nano urea @ 0.2% foliar spray twice @ 25 & 45 DAS, T_4: 50% recommended dose of N + nano urea @ 0.2% foliar spray twice @ 25 & 45 DAS, T_5: 75% recommended dose of N + nano urea @ 0.4% spray twice @ 25 & 45 DAS, T_6: 50 % recommended dose of N + Nano urea @ 0.4% spray @ 25 & 45 DAS, T_7: 75% recommended dose of N + nano urea @ 0.6% spray applied twice @ 25 & 45 DAS, T_8: 50% recommended dose of N + nano urea @ 0.6% spray @ 20 & 40 DAS, T_9: 75% recommended dose of N + Urea (2% spray) @ 20 & 40 DAS, T_{10}: 50% recommended dose of N + Urea (2% spray) @ 25 & 45 DAS. Two sprays of Nano urea (4% nitrogen) and normal urea (46% nitrogen) were done at 25 and 45 days after sowing, with a spray solution of 500 liters of water per hectare. The recommended dose of nitrogen was applied in three splits (50% at basal, 25% at 25 days and remaining 25% at 45 days after sowing). The treatments were replicated thrice in Randomized complete block design. The well known fodder oat variety RO-11-1 was sown during 3rd week of October at a row spacing of 25 cm. The cultural operations and other production practices were followed as per local recommendations. The crop was harvested when crop attained 50 per cent of flowering and the known quantity random sample green fodder was obtained from each plot at the time of harvest for the purpose of analyzing the quality of the fodder. These samples were dried in the sun for a few hours and then heated to 70±2 °C thermostatically controlled electric oven until they reached a constant weight. The known quantity of powdered samples was collected in order to analyze the nitrogen content of the plant using the micro-Kjeldahl method (Jackson, 1973) and other quality parameters. The yield of green fodder was converted into a dry matter yield (q/ha) based on the dry matter content of the samples; the same samples were also used to determine the yield and content of crude protein (A.O.A.C., 1965). The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez, 1984. Overall differences were tested by 'F' test at 5 per cent level of significance. In Case if signidicant results, critical difference (CD) at 5 per cent level of probability was calculated for testing the difference between the two treatment means. The economics was worked out with prevailing market price.

The Mysore Journal of Agricultural Sciences

Table 1

Growth parameters of fodder oat as influenced by nano-urea

Treatments	Plant height (cm)			Leaf Stem Ratio		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	98.6	104.6	101.6	0.41	0.36	0.38
T2 : RDF (Recommended dose of fertilizers) (N:P:K @100:40:30 kg/ha)	140.0	157.6	148.8	0.43	0.62	0.52
T3 : 75 % recommended dose of N + Nano urea @ 0.2 % spray	136.9	141.4	139.1	0.37	0.43	0.40
T4 : 50 % recommended dose of N + Nano urea @ 0.2 % spray	123.6	117.0	120.3	0.34	0.38	0.36
T5 : 75 % recommended dose of N + Nano urea @ 0.4 % spray	128.3	140.8	134.5	0.35	0.47	0.41
T6 : 50 % recommended dose of N + Nano urea @ 0.4 % spray	130.3	126.2	128.3	0.36	0.45	0.40
T7 : 75 % recommended dose of N + Nano urea @ 0.6 % spray	138.3	144.6	141.5	0.37	0.53	0.45
T8 : 50 % recommended dose of N + Nano urea @ 0.6 % spray	123.8	134.4	129.1	0.42	0.45	0.45
T9 : 75 % recommended dose of N + Urea (2 % spray)	138.0	143.5	140.8	0.38	0.58	0.48
T10 : 50 % recommended dose of N + Urea (2 % spray)	127.3	138.6	133.3	0.47	0.46	0.46
S. Em+	5.63	4.61	3.62	0.02	0.02	0.013
C.D at 5%	16.84	13.81	14.75	0.05	0.53	0.04

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 25 and 45 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two splits (50% N as basal and 25% at 25 days after sowing and remaining 25% at 45 days after sowing)

Results and Discussion

Growth Parameters : The mean plant height recorded at harvest was significantly influenced by varied nitrogen levels (Table 1). The significantly higher mean plant height was recorded with application of 100 per cent recommended dose of nitrogen (148.8cm). The control *i.e.,* without nitrogen application recorded significantly lower plant height (101.6 cm). This may be attributed to application of more nutrients during early vegetative and crop development stages, which led to maximum plant height. Apart from this nitrogen plays a pivotal role in photosynthetic activity and protein synthesis which might promote cell division and cell elongation that in turn accelerate vegetative growth. This is in conformity with the findings of Bhilare & Joshi, 2008; Rana *et al.* (2013); Somashekar *et al.* (2015); Lahri *et al.* (2021) and Navya *et al.* (2022).

The mean leaf stem ratio was significantly higher with application of 100 per cent recommended dose of nitrogen (0.52). Whereas, lower leaf stem ratio was recorded with no nitrogen application (0.38). It is mainly due to rapid expansion of dark green foliage which intercept more solar radiation for the production of photosynthates, which resulting in higher meristematic activity and nitrogen also influence on productivity of more functional leaves for a longer period of time. Similar results were reported by Kumawat *et al.* (2016); Vimal *et al.* (2017) and Lagad *et al.* (2020).

Yield Parameters : Application of 100 per cent recommended dose of fertilizers recorded higher green forage yield (338.7 q/ha), which was on par with application of 75 per cent recommended nitrogen with normal urea 2 per cent spray and nano urea @ 0.6 per cent spray twice at 25 and 45 days after sowing (322.3 q and 306.4 q ha^{-1}, respectively) (Table 2). The no nitrogen treatment (control), recorded significantly lower mean green fodder yield (210.8 q ha^{-1}). The nano urea applied treatment recorded lower yield as compare to normal urea due to low nitrogen content in nano urea and it is not sufficient meet out the requirement of the crop. This is mainly due to nitrogen plays a pivotal role in metabolic process in plants such as cell division and expansion, enzymatic

TABLE 2

Yield parameters of fodder oat as influenced by nano-urea

Treatments	Green Forage Yield (q ha^{-1})			Dry Matter Yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	171.7	249.8	210.8	33.8	47.0	40.4
T2 : RDF (Recommended dose of fertilizers) (N:P:K @100:40:30 kg/ha)	299.8	377.7	338.7	66.4	88.7	77.5
T3 : 75 % recommended dose of N + Nano urea @ 0.2 % spray	251.3	304.7	278.0	51.5	62.5	57.0
T4 : 50 % recommended dose of N + Nano urea @ 0.2 % spray	213.6	276.1	244.9	45.2	54.3	49.8
T5 : 75 % recommended dose of N + Nano urea @ 0.4 % spray	269.4	299.4	284.4	52.7	64.6	58.7
T6 : 50 % recommended dose of N + Nano urea @ 0.4 % spray	218.6	288.8	253.7	43.0	62.5	52.7
T7 : 75 % recommended dose of N + Nano urea @ 0.6 % spray	277.5	335.4	306.4	56.3	76.4	66.4
T8 : 50 % recommended dose of N + Nano urea @ 0.6 % spray	226.8	298.8	262.8	44.9	62.7	53.8
T9 : 75 % recommended dose of N + Urea (2 % spray)	285.8	358.7	322.3	62.4	83.0	72.7
T10 : 50 % recommended dose of N + Urea (2 % spray)	245.0	307.8	276.4	47.6	69.4	58.5
S.Em+	14.2	16.7	9.7	4.6	3.8	2.4
C.D at 5%	42.5	49.9	29.05	13.8	11.4	7.19

Note : RDF = Recommended dose of fertilizers; ·Nano urea and urea was sprayed at 25 and 45 days after sowing and recommended dose of P and K is common for all treatments;Application of recommended dose of nitrogen in two splits (50% N as basal and 25% at 25 days after sowing and remaining 25% at 45 days after sowing)

activity, photosynthetic efficiency, meristematic activity which led to better vegetative growth which is evidenced by higher plant height and leaf stem ratio and in turn resulted higher green biomass production. The findings of Patel *et al*. (2007); Singh & Sumeria (2010); Dubey *et al*. (2013); Bhoya *et al*. (2013) and Meena *et al*. (2021) also confirmed the same results. The highest forage yield with nano urea was confirmed with the findings of Abdel (2018); Naveena *et al*. (2021a) and Shekara *et al*. (2022).

Application of recommended dose of fertilizer recorded significantly higher dry matter yield on pooled basis (77.5 q ha^{-1}), which was on par with application of 75 per cent recommended nitrogen along with normal urea 2 per cent spray twice at 25 and 45 days after sowing (72.7 q ha^{-1}) (Table 2). The no-nitrogen treatment (control) recorded significantly lower dry matter yield (40.4 q ha^{-1}), The increased dry matter yield might be due to enhanced crop growth and photosynthetic activity which led to better supply of carbohydrates, better partitioning of photosynthates and higher accumulation of nutrients ultimately resulted in higher dry matter content and green biomass yield, which led to higher dry matter yield. The similar findings were reported by Singh *et al.* (2012); Meena *et al.* (2021); Naveena *et al*. (2021b) and Theerthana *et al*. (2022).

The crude protein yield is one of the important quality parameters and it was significantly influenced by nitrogen levels. Application of 75 per cent recommended nitrogen along with 2 per cent urea spray twice at 25 and 45 days after sowing recorded significantly higher yield (4.51 q ha^{-1}), whereas control recorded lowest crude protein yield (2.05 q ha^{-1}). The similar trend was noticed with total digestible crude protein yield. This might be due to nitrogen which is constituent of amino acids and regulates cellular metabolism of amino acids and proteins that forms biological catalysts of phosphorylated compounds involved in energy transformation. Nitrogen is a structural constituent of cell and cell wall, thus, increasing the quality of fodder by improving the protein content. Similar results were reported by Shekara *et al.* (2015) and Meena *et al.* (2021).

TABLE 3

Quality parameters of fodder oat as influenced by nano-urea

Treatments	Crude Protein (%)			Crude fiber (%)			Crude Protein Yield (q ha^{-1})			Crude fiber Yield (q ha^{-1})		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	5.13	5.03	5.08	33.8	33.8	33.8	1.73	2.38	2.05	11.4	15.9	13.7
T2 : RDF (Recommended dose of fertilizers) (N:P:K @100:40:30 kg/ha)	4.80	4.47	4.63	25.2	23.4	24.3	3.19	3.97	3.59	16.7	20.8	18.8
T3 : 75 % recommended dose of N + Nano u rea @ 0.2 % spray	6.40	6.37	6.38	26.5	25.6	26.1	3.26	4.00	3.63	13.7	16.0	14.8
T4 : 50 % recommended dose of N + Nano urea @ 0.2 % spray	5.83	5.37	5.60	27.5	27.5	27.5	2.65	2.91	2.79	12.4	14.9	13.7
T5 : 75 % recommended dose of N + Nano urea @ 0.4 % spray	4.67	4.53	4.60	27.0	26.9	26.9	2.45	2.93	2.70	14.3	17.4	15.8
T6 : 50 % recommended dose of N + Nano urea @ 0.4 % spray	4.40	4.37	4.38	28.7	27.3	28.0	1.89	2.73	2.31	12.3	17.0	14.8
T7 : 75 % recommended dose of N + Nano urea @ 0.6 % spray	5.57	5.77	5.67	27.3	26.4	26.9	3.13	4.40	3.75	15.3	20.4	17.9
T8 : 50 % recommended dose of N + Nano urea @ 0.6 % spray	5.40	5.13	5.27	26.9	27.4	27.2	2.44	3.23	2.85	12.1	17.2	14.7
T9 : 75 % recommended dose of N + Urea (2 % spray)	6.30	6.10	6.20	24.0	23.5	23.8	3.92	5.07	4.51	15.0	19.5	17.3
T10 : 50 % recommended dose of N + Urea (2 % spray)	5.43	5.53	5.48	26.6	27.6	27.1	2.59	3.84	3.20	12.7	19.1	15.9
S.Em+	0.19	0.17	0.17	0.72	0.7	0.5	0.26	0.27	0.16	1.2	1.3	0.8
C.D at 5%	0.57	0.52	0.49	2.15	2.06	1.61	0.79	0.80	0.47	NS	NS	2.43

Note : RDF = Recommended dose of fertilizers; Nano urea and urea was sprayed at 25 and 45 days after sowing and recommended dose of P and K is common for all treatments; Application of recommended dose of nitrogen in two splits (50% N as basal and 25% at 25 days after sowing and remaining 25% at 45 days after sowing)

TABLE 4

Economics of fodder oat as influenced by nano-urea

Treatments	Gross returns (Rs./ha)			Net returns (Rs./ha)			B:C ratio		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T1 : Control (without N)	38626	56213	47419	14083	30670	22376	1.57	2.20	1.89
T2 : RDF (Recommended dose of fertilizers) (N:P:K @100:40:30 kg/ha)	67453	84975	76214	41689	58211	49950	2.62	3.17	2.90
T3 : 75 % recommended dose of N + Nano urea @ 0.2 % spray	56546	68558	62552	28846	39858	34352	2.04	2.39	2.22
T4 : 50 % recommended dose of N + Nano urea @ 0.2 % spray	48069	62115	55092	20674	33720	27197	1.75	2.19	1.97
T5 : 75 % recommended dose of N + Nano urea @ 0.4 % spray	60620	67361	63990	31920	37661	34790	2.11	2.27	2.19
T6 : 50 % recommended dose of N + Nano urea @ 0.4 % spray	49179	64980	57080	20824	35625	28225	1.73	2.21	1.97
T7 : 75 % recommended dose of N + Nano urea @ 0.6 % spray	62433	75465	68949	32813	44845	38829	2.11	2.46	2.29
T8 : 50 % recommended dose of N + Nano urea @ 0.6 % spray	51026	67230	59128	21711	36915	29313	1.74	2.22	1.98
T9 : 75 % recommended dose of N + Urea (2 % spray)	64298	80715	72506	38085	53502	45793	2.45	2.97	2.71
T10 : 50 % recommended dose of N + Urea (2 % spray)	55118	69255	62187	29210	42347	35779	2.13	2.57	2.35

Note : Cost of nano urea- Rs.480/litre; Cost of Urea- Rs.5.62/kg; Selling price of green fodder – Rs.225 q^{-1}

The crude fiber yield was significantly influenced by nitrogen levels and concentrations of nano urea (Table 6). The 100 per cent recommended nitrogen recorded significantly higher crude fiber yield (18.83 q ha^{-1}). Whereas, no nitrogen treatment recorded lower crude fiber yield (13.67 q ha^{-1}). The increase in crude fiber yield with higher level of nutrients is mainly due to higher dry matter production and crude fiber content. Higher level of fertilizers application delay the maturity particularly by nitrogen. Whereas, lower dose of fertilizers application leads to forced maturity with short life span of time and this might be governing the phenomenon of fiber syntheses. This is in agreement with the findings of Pathan *et al.* (2012) and Singh *et al.* (2012).

Economic analysis : The higher mean gross returns, net returns and benefit cost ratio was recorded with application of 100 per cent recommended dose of fertilizer (Rs.76214 ha^{-1}, Rs.49950 ha^{-1} and 2.90, respectively) followed by application of 75 per cent nitrogen along with normal urea 2 per cent spray twice at 25 & 45 days after sowing (Rs.72506 ha^{-1}, Rs.45793 ha^{-1} and 2.71, respectively). The no nitrogen treatment recorded lower net returns (Rs.22376 ha^{-1}) and BC ratio (1.89). The increased net returns and B:C ratio may be due to higher green forage yield with lower cost of cultivation which resulted in higher gross and net returns. Similar results were reported by Yogendra *et al.* (2020), Mohammad (2021) and Ajithkumar *et al.* (2021).

Based on the results it can be inferred that 100 per cent recommended dose of fertilizers or 75 per cent recommended nitrogen along with normal urea 2 per cent spray or 0.6 per cent of nano urea twice at 25 and 45 days after sowing found viable and economical for getting higher green forage yield and quality in fodder oats under southern dry zone of Karnataka.

Acknowledgement : The authors are grateful to AICRP on Forage crops & Utilization, IGFRI, Jhansi and University of Agricultural Sciences, Bangalore for financial support and facilities for carryout research work at Zonal Agricultural Research Station, V. C. Farm, Mandya.

References

ABDEL, S. M. A., 2018, Response of lettuce (*Lactuca sativa* L.) to foliar spray using nano-urea combined with mycorrhiza. *J. Soil Sci. Agric. Eng*., **9** (10) : 467 - 472.

AJITHKUMAR, K., KUMAR, Y., SAVITHA, A. S., AJAYAKUMAR, M. Y., NARAYANASWAMY, C., RALIYA, R., KRUPASHANKAR M. R. AND BHAT, S. N., 2021, Effect of IFFCO nano fertilizer on growth, grain yield and managing *turcicum* leaf blight disease in maize. *Int. J. Plant Soil Sci*., **33** (16) : 19 - 28.

AL-JUTHERY, H. W. A. AND SAADOUN, S. F., 2018, Impact of foliar application of micronutrients nano fertilizers on growth and yield of Jerusalem. *Artichoke,* **49** (4) : 577 - 585. http://TIJAS.2018.

A.O.A.C., 1965, Official methods of analysis of the association of official agricultural chemists, 10th Edn., Washington DC, pp. : 744 - 745.

BHILARE, R. L. AND JOSHI, Y. P., 2008, Response of oat (*Avena sativa* L.) to nitrogen levels under different cutting management. *J. Maharashtra agri .Univ.,* **33** (3) : 312 - 314.

BHOYA, M., CHAUDHARI, P. P., RAVAL, C. H. AND BHATI, P. K., 2013, Effect of nitrogen and zinc on yield and quality of fodder sorghum (*Sorghum bicolor* L. Moench) varieties. *Forage Res*., **39** (1) : 24 - 26.

DEROSA, M., MONREAL, C. AND SCHNITZER, M., 2010, Nanotechnology in fertilizers. *Nature Nanotech,* **5** : 91. https://doi.org/10.1038/nnano.2010.2

DUBEY, ABHIJEET., RATHI, G. S. AND SAHU, R, 2013, Effect of nitrogen levels on green fodder yield of oat (*Avena sativa* L.) varieties. *Forage Res.,* **39** (1) : 39 - 41.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedures for agricultural research with emphasis on rice. International Rice Research Institute, Los Banos, Philippines, pp. : 268.

GURU, T., VERONICA, N., THATIKUNTA, R., REDDY, S. N., 2015, Crop nutrition management with nano fertilizers. *Int. J. Environ. Sci. Technol.,* **1** (1) : 4 - 6.

HUSEN, A. AND IQBAL, M., 2019, Nanomaterials and plant potential. Springer, Cham, DOI : 10.1007/978-3-030-05569-1_1.

JACKSON, M. L., 1973, Soil chemical analysis. Prentice hall of India Pvt. Ltd., New Delhi, pp. : 498.

KUMAR, Y., SINGH, T. T. AND RALIYA, R., 2021, Nanofertilizers and their role in sustainable agriculture. *Ann. Plant Soil Res.*, **23** (3) : 238-255.

KUMAR, Y., TIWARI, K. N., NAYAK, R. K., ABHIMANYURAI, SINGH, S, P., KUMAR, Y., TOMAR, H., SINGH, T. AND RALIYA R., 2020a, Nano fertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season cops of Uttar Pradesh. *Ind. J. Ferti*., **16** (8) : 772 - 786.

KUMAR, Y., TIWARI, K. N., SINGH, T., SAIN, N. K., LAXMI, S., VERMA, R., SHARMA, G. C. AND RALIYA, R., 2020b, Nano fertilizers for enhancing nutrient use efficiency, crop productivity and economic returns in winter season crops of Rajasthan. *Ann. Plant Soil Res*., **22** (4) : 324 - 335.

KUMAWAT, S. M., MOHD, A. SHEKHAWAT, S. S. AND KANTWA, S. R., 2016, Effect of nitrogen and cutting management on growth, yield and quality of fodder pearl millet (*Pennisetum glaucum* L.) cultivars. *Range Mgmt. Agrofor*., **37** (2) : 207 - 213.

LAGAD, P., PATHAN, S., DAMAME, S. AND SINARE, B., 2020, Effect of foliar nutrient management on growth, yield and quality of summer forage sorghum. *Forage Res*., **46** (3) : 271 - 273.

LAHARI, S., HUSSAIN, S. A., PARAMESWARI, Y. S. AND SHARMA, S. H. K., 2021, Grain yield and nutrient uptake of rice as influenced by the nano forms of nitrogen and zinc. *Int. J. Environ. Climate Change*, **11** (7) : 1 - 6.

MEENA, S., SHWETA, KUMAR, S., KUMAR, R., TOKAS, J., NEELAM, DEVI, U. AND SATPAL, 2021, Response of spring planted fodder maize to nitrogen and phosphorus levels. *Forage Res*., **46** (4) : 363 - 367.

MOHAMMAD, R., 2021, Moisture stress mitigation in forage sorghum through foliar nutrition during summer season. *M.Sc. Thesis* submitted to College of

Agriculture, CCS Haryana Agriculture University, Hisar.

NAVEENA, H, SHEKARA, B. G., MANOJ, K. N. AND CHIKKARUGI, N. M., 2021b, Effect of different organic sources of nutrients on green fodder yield, nutrient uptake and economics of fodder maize and succeeding fodder cowpea under maize-cowpea cropping system, *Forage Res.,* **47** (1) : 130 - 134.

NAVEENA, B. M., SHEKARA, B. G., VISHWANATH, A. P., KALYANA MURTHY, K. N. AND CHIKKARUGI, N. M., 2021a, Effect of times of sowing and nitrogen levels on growth and seed yield of fodder oats (*Avena sativa* L.). *J. Pharm. Innov*., **10** (12) : 2752 - 2756.

NAVYA, K., KUMAR, S. R., CHAITANYA, K. A. AND SAMPATH, O., 2022, Effect of nano nitrogen in conjunction with urea on growth and yield of mustard (*Brassic juncea* L.) in Northern Telangana Zone. *Biol. Forum - An Int. J*., **14 (**3) : 95 - 99.

PATEL, A. S., BAREVADIA, T. N., PATEL, M. R., SADHU, A. C. AND PARMAR, H. P., 2007, Effect of nitrogen and different management practices on growth and seed production of oat (*Avena sativa* L.). *Forage Res.,* **4** : 104 - 108.

PATHAN, S. H., TUMBARE, A. D. AND KAMBLE, A. B., 2012, Impact of planting material, cutting management and fertilizers levels on nutritional quality of bajra. *Forage Res.,* **38** (2) : 74 - 79.

RANA, D. S., SINGH, B., GUPTA, K., DHAKA, A. K. AND PAHUJA, S. K., 2013, Effect of fertility levels on growth, yield and quality of multicut forage sorghum (*Sorghum bicolor* L. Moench) genotypes. *Forage* Res., **39** (1) : 36 - 38.

SHEKARA, B. G., LOHITHASWA, H. C., CHIKKARUGI, N. M. AND MANASA N., 2015, Fodder production potential of maize grown for baby corn and green cob in different cropping systems. *Forage Res*., **41** (2) : 92 - 94.

SHEKARA, B. G., MAHADEVU, P., CHIKKARUGI, N. M. AND MANASA N., 2022, Green forage yield, nutritional value and economics of fodder oat genotypes as influenced by nitrogen levels. *Mysore J. Agric. Sci.,* **56** (2) : 339 - 344.

SHEKARA, B. G., MAHADEVU, P., CHIKKARUGI, N. M. AND MANASA, N., 2019, Fodder and livestock scenario in Karnataka. In: Indian fodder scenario: Redefining state wise status (eds. A. K. Roy, R. K. Agrawal, N. R. Bhardwaj). ICAR- AICRP on forage crops and utilization, Jhansi, India, pp. : 79 - 90.

SINGH, P. AND SUMERIA, H. K., 2010, Effect of nitrogen levels on fodder and economics of multicut forage sorghum (*Sorghum bicolor* L. Moench) genotypes. *Forage Res*., **36** (1) :15 - 18.

SINGH, P., SUMERIYA, H. K., SOLANKI, N. S. AND MURDIA, A., 2012, Productivity, economics and quality of fodder sorghum under varying levels of nitrogen and phosphorus. *Annals Plant Soil Res*., **14 (**2) : 127 - 129.

SINGH, P., SUMERIYA, H. K., SOLANKI, N. S. AND MURDIA, A., 2012, Productivity, economics and quality of fodder sorghum under varying levels of nitrogen and phosphorus. *Ann. Pl. Soil Res.,* **14** (2) : 127 - 129.

SOMASHEKAR, K. S., SHEKARA, B. G., KALYANAMURTHY, K. N. AND LOHITHASWA, H. C., 2015, Growth, yield and economics of multicut fodder sorghum (*Sorghum sudanese* L.) as influenced by different seed rates and nitrogen levels. *Forage Res*., **40** (4) : 247 - 250.

THEERTHANA, T., YOGANANDA, S. B., THIMMEGOWDA, M. N., JAYADEVA, H. M., PRAKASH, S. S. AND GOWDA, A. P. M., 2022, Nano nitrogen and nano zinc fertilizers: Impact on sustainable paddy production under different systems of establishment. *Mysore J. Agric. Sci.*, **56** (3) : 272 - 278.

VIMAL, K. S., KUMAWAT, M., MOHD, A. AND VERMA, J., 2017, Growth and quality of forage pearl millet (*Pennisetum americanum* L.) as influenced by nitrogen and zinc levels in hyper arid region of Rajasthan. *Forage Res*., **43** (2) : 125 - 129.

YOGENDRA, K., TIWARI, K. N., NAYAK, R. K., ABHIMANYURAI, S. P., SINGH, A. N. AND SINGH, 2020, Nano fertilizers for increasing nutrient use efficiency, yield and economic returns in important winter season crops. *Indian J. Fert*., **16** (8) : 772 - 786.