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Effect of nano urea on growth, yield attributes and yield of summer pearl millet [*Pennisetum glaucum* (L.) R. Br.] under real time nitrogen management

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Abstract
A field experiment was carried out under medium black calcareous soil during summer seasons of 2022 and 2023 at the Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, India, with effect of nano urea on growth, yield and economics of summer pearl millet under real time nitrogen management The results of experiment indicated that overall growth of the crop *viz*., plant height, number of total tillers per plant, dry matter per plant at 60 DAS and at harvest, physiological parameters *viz*., CGR at different stages, SPAD value at 45 DAS and leaf chlorophyll content, yield attributes and yield *viz*., number of effective tillers per plant, earhead length, earhead girth, grain yield, fodder yield and earhead weight of pearl millet were significantly higher with the application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC ≤ 4 in comparison to other treatments.

Keywords: Pearl millet, leaf colour chart (LCC), nano urea, foliar sprays, growth and yield

Introduction
Pearl millet is the most widely grown staple food of majority of poor and small land holders in Asia and Africa. It is also consumed as feed and fodder for livestock. It accounts for almost half of global millet production. It is the sixth most important cereal crop in the world next to maize, rice, wheat, barley and sorghum.

It occupies an area of 70.08 lakh hectares with an average production of 95.31 lakh tonnes and productivity of 1360 kg/ha in India during 2023-24 (Anon., 2023a) [1]. The major pearl millet growing states are Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana contributing 90% of total national production. In Gujarat, it is grown in 26 out of 33 districts covering an area of 1.97 lakh hectares and production of 3.50 lakh tones with average productivity of 1777 kg/ha (2023-24) during *kharif* season. In summer season pearl millet occupies an area of 3.15 lakh hectares and production of 9.37 lakh tones with average productivity of 2971 kg/ha as well as in coastal area pearl millet grown during semi *rabi* season around of 0.066 lakh hectares and production of 0.159 lakh tones with average productivity of 2428 kg/ha (2023-24). The total area of pearl millet in the Gujarat state is 5.19 lakh hectares and production of 13.04 lakh tones with average productivity of 2511 kg/ha in 2023-24 (Anon., 2023b) [2]. The area of summer cultivation is increasing gradually due to short period of time window is available to farmer after *rabi* crops, acute demand of fodder in summer season and suitable climatic situation in the state.

Nano fertilizers consist of nanomaterials, which are defined as materials in size range of 1 to 100 nm at least in one dimension. Due to higher surface area to volume size ratio, their availability and absorption is manifold. They have dynamic physical and chemical properties over their conventional counterparts. The World's first 'Nano Urea' introduced by IFFCO during the year 2021-22. The size of one nano particle of urea is 55000 times smaller than one granule of urea. Nano urea contains 4.0% total nitrogen (w/v). These particles are evenly dispersed in water. Nano urea because of its small size (20-50 nm) and higher use efficiency (> 80%), when sprayed on leaves of plant (2-4 ml/liter) at critical growth stages, it increases the instant availability of

nutrients to the growing plant parts, increases chlorophyll formation, rate of photosynthesis, dry matter production and thus overall growth of the plants. Nano urea (30-40 nm) can easily penetrate the stomata and easily get entered through plasmodesmata (40 nm) and subsequently take part into the metabolism by binding itself with various carrier proteins. Unused nitrogen is retained in the plant vacuole and released slowly for appropriate plant growth and development.

The leaf colour chart (LCC) is an innovative cost effective tool for real-time or crop-need-based N management (Balasubramanian *et al.*, 1999) [5]. LCC is a visual and subjective indicator of plant nitrogen deficiency and is an inexpensive, easy to use and simple alternative to chlorophyll meter/ SPAD meter (Soil Plant Analysis Development). It measures leaf colour intensity that is related to leaf N status. LCC is an ideal tool to optimize N use in rice, wheat and maize at high yield levels, irrespective of the source of N applied *viz*., organic manure, biologically fixed N or chemical fertilizers. Thus, it is an eco-friendly tool in the hands of farmers. Now, it is manufactured with 4 colours called Four Panel LCC (Fig. 1) and 6 colours called Six Panel LCC (Fig. 2). Moreover, LCC is provided with water-proof laminated instruction sticker in the required regional language.

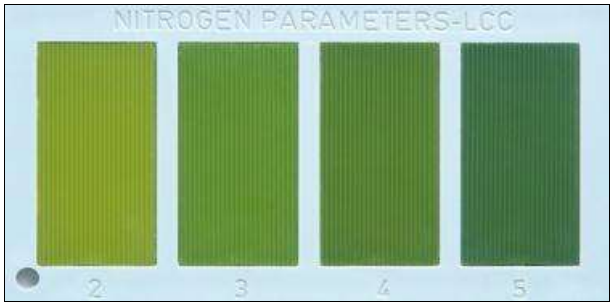

Fig 1: 4 panel leaf colour chart

Fig 2: 6 panel leaf colour chart

Materials and Methods

The present investigation entitled "Effect of nano urea on growth and yield of summer pearl millet [*Pennisetum glaucum* (L.) R. Br.] under real time nitrogen management" was carried out for two consecutive years during the summer seasons of 2022 and 2023 at the Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, which is geographically situated at the latitude of 22.3^0 N, longitude of 70.0^0 E and at an altitude of 7.77 m above mean sea level. It lies under North Saurashtra zone-VI of Gujarat state. It enjoys a typically subtropical climate characterized by moderately cold and moist winter, moderately hot and dry summer and warm and moderately humid monsoon. The rainy season commences in the second fortnight of June and ends by September with an average rainfall of 722.5 mm (average of last 10 years). July and August are the months of heavy rainfall. Winter sets in the month of November and continues till the month of February. January is the coldest month of winter. Summer season commences during the second fortnight of February and ends by middle of June. April and May are the hottest months of summer.

The experiment was carried out with 10 treatments and laid out in randomized block design with three replications comprising *viz*., 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + 40 kg N/ha through urea at 40-45 DAS (T_1), 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_2), 40 kg N/ha as basal + 30 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_3), 40 kg N/ha as basal + 20 kg N/ha through urea at 25-30 DAS + four foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_4), 40 kg N/ha as basal + 20 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_5), 40 kg N/ha as basal + 10 kg N/ha through urea at 25-30 DAS + four foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_6), 40 kg N/ha as basal + 10 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_7), 40 kg N/ha as basal + four foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_8), 40 kg N/ha as basal + three foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_9) and control (T_{10}). The soil of the experimental plot was clayey in texture, low in organic carbon, slightly alkaline in reaction with pH and EC with medium in available nitrogen (265 kg/ha), medium in available phosphorus (37.1 kg/ha) and higher in available potash (313 kg/ha).

The required quantity of soil applied fertilizer and foliar application of nano urea for each plot as per treatments. Soil applied nitrogen was applied in three equal split *i.e.* basal, 25-30 DAS and at 40-45 DAS from DAP, Urea fertilizers and foliar spray of nano urea as per treatment. The full dose of phosphorus was applied uniformly in all the treatments at basal in the form of DAP fertilizer. The furrows were lightly covered with soil after fertilizer application in all the plots. The periodical plant protection measures for pearl millet crop were followed to save the crop from pests and diseases. The pearl millet crop was harvested manually. Different growth and yield components were recorded periodically. Economics were worked out based on prices of output and input in the crop season. The data Where subjected to standard analysis of variance technique. The mean treatment were compared at $p< 0.05$ level of significance.

Results and Discussion

Growth parameters

The results showed that, growth parameters were significantly affected by different real time nitrogen management treatments (Table 1 to 2). According to the study application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_2) significantly increased plant height at 45 DAS and at harvest, number of total tillers per plant and dry matter per plant at 60 DAS and harvest. which was remained at par with 40 kg N/ha as basal + 30 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC $\leq$ 4 (T_3) and 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + 40 kg N/ha through urea at 40-45 DAS (T_1) as compared with rest of treatment combinations. The growth parameter was not positively affected at dry matter per plant at 30 DAS by different treatments. LCC based on nano urea application was influence on the metabolism

of developing plant which leads to increase in plant height, number of total tillers per plant and dry matter per plant in pearl millet. It is closely associated with cell division, growth and elongation, as well as rapid root development and chlorophyll creation which increase photosynthesis. These gains may be attributable to early and abundant nitrogen availability based on foliar applied nano urea as evidenced from improvement in the nutritional status of plants at various growth stages of crop, which created a superior nutritional environment for root zone growth and development. These findings are in accordance with the results reported by Barkha Rani *et al.* (2019) [6], Attri *et al.* (2022) [4], Bhat *et al.* (2022) [7], Kashyap and Bainade (2022) [11], Sharma *et al*. (2022) [19], Choudhary *et al.* (2023) [8], Pedireddy *et al.* (2024) [15] and Soundarya *et al.* (2024) [24].

Physiological parameters

The data in (Table 3 to 4) showed all the different real time nitrogen management treatments were significantly affected to physiological parameters. In pearl millet significantly influenced crop growth rate for the period of 30 DAS to 60 DAS, 60 DAS to at harvest, SPAD value at 45 DAS and leaf chlorophyll content at threshold value of LCC were observed with application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_2) and it was statistically at par with 40 kg N/ha as basal + 30 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_3) and 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + 40 kg N/ha through urea at 40-45 DAS (T_1) as compared with rest of treatments but crop growth rate for the period of 0 to30 DAS and relative growth rate for the period of 30 DAS to 60 DAS and 60 DAS to harvest in pearl millet. Here, the reason might be that the use of nano fertilizers boosted the total leaf chlorophyll content and photosynthetic rate, which causes photosynthetic materials to be transformed into different plant parts. The nanourea has larger surface area and the particle size is less than the pores of root and leaves of plant which increased the quick absorption of nutrients and lead to the increased rate of photosynthesis in pearl millet. LCC based nano urea provided pearl millet with a greater quantity of nitrogen throughout the growth period, which increased the amount of chlorophyll in the plants. These results are accordance with the findings of Sharma *et al.* (2022) [19] and Sneha *et al*. (2023) [23]. The higher SPAD value may be due to the adequate supply of nutrients and metabolites for growth and development by foliar application of nano urea. These findings were in close agreement with Saud *et al.* (2022) [18] and Harode *et al.* (2024) [9]. Application of nano fertilizers increased the plant height, leaf area, dry matter production, chlorophyll content, photosynthetic rate which induces the transformation of photosynthetic materials to various parts of the plant and which was increased the crop growth rate of the plant. Similar finding was observed by Choudhary *et al.* (2023) [8], Singh *et al.* (2023b) [22] and Shree *et al.* (2024) [20].

Yield attributes

Among the various real time nitrogen management treatments investigated (Table 5) application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_2) revealed significantly increase number of effective tillers per plant, earhead length and earhead girth and which was followed by treatments 40 kg N/ha as basal + 30 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_3) and 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + 40 kg N/ha through urea at 40-45 DAS (T_1). This indicates that all these parameters increased with sufficient supply and availability of nitrogen and their transfer to the sink. Application of nano urea resulted in higher growth and yield parameters mainly due to LCC based foliar application of nano urea supplied the nutrients directly to plant by increasing the availability and also due to size of nano particles resulted in increased availability to plants. It leads to meristematic cell activity, stimulation of cell elongation in crops and improve photosynthesis rate. These findings were in close agreement with Tarafdar *et al*. (2019) [26], Arya *et al*. (2022) [3], Bhat *et al.* (2022) [7], Kashyap and Bainade (2022) [11], Parve *et al.* (2023) [14] and Soundarya *et al.* (2024) [24].

Yield parameters

The results related to grain yield, fodder yield and earhead weight showed significant differences between different real time nitrogen management treatments combinations (Table 6). Application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_2) revealed significantly increase grain yield, fodder yield and earhead weight and which was followed by treatments 40 kg N/ha as basal + 30 kg N/ha through urea at 25-30 DAS + three foliar sprays of nano urea 0.4% when LCC ≤ 4 (T_3) and 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + 40 kg N/ha through urea at 40-45 DAS (T_1) but there was not any positive impact on test weight in pearl millet. The positive effects of nitrogen on increasing the size of the source and establishing the best possible source to sink link may be responsible for the rise in grain production. Nanourea particles are smaller than conventional urea particles, which could improve their solubility and nutritional availability. Higher pearl millet yield may result from it enhanced nutrient uptake, especially nitrogen, which can enhance plant growth and development. Plant growth characteristics like plant height, leaf area and chlorophyll content all have been shown to be improved by foliar application nano urea based on LCC. Elevated photosynthetic efficiency can help pearl millet produce more grain and accumulate more biomass. Similar findings was reported by Rathnayaka *et al.* (2018) [17], Kumar *et al.* (2020) [12], Jadhav *et al.* (2022) [10], Kashyap and Bainade (2022) [11], Parve *et al.* (2023) [14], Ranjan *et al.* (2023) [16], Srivastava *et al.* (2023) [25] and Shree *et al.* (2024) [20]. On the other hand, improved morphological characteristics were credited with increasing fodder production. Nano urea formulations are often developed to improve nutrient uptake efficiency. By enhancing the availability and uptake of nutrients including nitrogen, nano urea has the potential to promote plant growth including fodder biomass production. Similar finding was observed by Parve *et al.* (2023), Ranjan *et al.* (2023) [16], Singh *et al.* (2023a) [21], Maurya *et al.* (2022) [13], Srivastava *et al.* (2023) [25] and Soundarya *et al.* (2024) [24].

Table 1: Effect of real time nitrogen management on plant height at 45 DAS, at harvest and number of total tillers per plant of pearl millet

Treatments	Plant height at 45 DAS (cm)			Plant height at harvest (cm)			Number of total tillers per plant		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	104.97	109.31	107.14	206.73	210.40	208.56	5.15	5.20	5.17
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	112.30	115.97	114.14	216.57	220.83	218.70	5.30	5.38	5.34
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	108.63	111.31	109.97	208.79	216.24	212.51	5.22	5.32	5.27
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS +Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	100.63	103.64	102.14	202.23	207.90	205.06	5.06	5.12	5.09
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	97.97	99.97	98.97	197.73	205.81	201.77	4.91	5.04	4.97
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	96.63	97.64	97.14	195.51	198.98	197.25	4.88	4.96	4.92
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	94.97	98.64	96.80	196.02	197.05	196.53	4.79	4.85	4.82
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	92.63	95.97	94.30	190.25	194.13	192.19	4.63	4.78	4.70
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	91.63	93.64	92.64	187.81	189.54	188.67	4.46	4.66	4.56
T_{10}: Control (without N application)	85.97	87.64	86.80	179.89	185.36	182.63	4.33	4.45	4.39
SEm±	2.92	3.13	2.14	6.87	7.19	4.97	0.16	0.15	0.11
C.D. at 5%	8.66	9.29	6.13	20.41	21.37	14.28	0.47	0.46	0.32
C.V. %	5.12	5.34	5.23	6.00	6.15	6.08	5.60	5.34	5.47
Y × T									
SEm±	3.02			7.03			0.16		
C.D. at 5%	NS			NS			NS		

Table 2: Effect of real time nitrogen management on dry matter per plant at 30, 60 DAS and at harvest of pearl millet

Treatments	Dry matter per plant at 30 DAS (g)			Dry matter per plant at 60 DAS (g)			Dry matter per plant at harvest (g)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	4.62	4.67	4.64	46.85	47.44	47.14	80.31	82.40	81.35
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.82	4.87	4.85	48.28	49.09	48.69	81.93	83.98	82.95
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.75	4.78	4.77	47.23	47.78	47.51	80.66	82.97	81.81
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS +Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.52	4.61	4.56	45.21	45.71	45.46	79.01	81.07	80.04
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.46	4.52	4.49	41.06	42.59	41.82	74.94	76.99	75.96
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.41	4.50	4.45	39.35	40.56	39.95	72.87	74.59	73.73
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.35	4.44	4.39	38.36	38.82	38.59	71.69	72.81	72.25
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.28	4.40	4.34	36.29	37.30	36.80	69.78	70.80	70.29
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4.16	4.35	4.25	34.09	35.39	34.74	67.72	69.01	68.37
T_{10}: Control (without N application)	4.04	4.29	4.17	31.78	32.80	32.29	64.79	66.80	65.79
SEm±	0.20	0.23	0.15	2.24	2.01	1.51	2.40	2.43	1.71
C.D. at 5%	NS	NS	NS	6.67	5.97	4.32	7.14	7.21	4.90
C.V. %	7.87	8.82	8.37	9.51	8.33	8.93	5.59	5.52	5.56
Y × T									
SEm±	0.22			2.13			2.41		
C.D. at 5%	NS			NS			NS		

Table 3: Effect of real time nitrogen management on crop growth rate between 0 to 30 DAS, 30 to 60 DAS and 60 DAS to harvest of pearl millet

Treatments	Crop growth rate (g/m^2/day) between 0 to 30 DAS			Crop growth rate (g/m^2/day) between 30 to 60 DAS			Crop growth rate (g/m^2/day) between 60 DAS to harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	2.38	2.39	2.38	21.69	21.95	21.82	19.07	20.55	19.81
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.51	2.55	2.53	22.61	23.16	22.89	19.51	20.81	20.16
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.43	2.46	2.45	21.66	22.12	21.89	18.90	20.66	19.78
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS +Four foliar sprays of Nno Urea 0.4% when LCC ≤ 4	2.34	2.36	2.35	21.13	20.86	20.99	18.08	20.57	19.32
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.25	2.33	2.29	18.44	19.65	19.04	17.39	19.83	18.61
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.27	2.32	2.29	18.02	18.54	18.28	16.81	18.44	17.63
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.23	2.30	2.26	17.41	17.91	17.66	16.75	18.77	17.76
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.16	2.26	2.21	16.20	16.98	16.59	15.44	18.23	16.84
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.12	2.23	2.17	15.13	15.91	15.52	14.54	17.07	15.81
T_{10}: Control (without N application)	1.99	2.14	2.07	13.65	14.20	13.92	13.57	15.79	14.68
SEm±	0.16	0.16	0.12	1.40	1.30	0.96	0.72	0.72	0.51
C.D. at 5%	NS	NS	NS	4.16	3.87	2.74	2.13	2.15	1.46
C.V. %	12.35	12.19	12.27	13.03	11.80	12.42	7.29	6.57	6.91
Y × T									
SEm±	0.16			1.35			0.72		
C.D. at 5%	NS			NS			NS		

Table 4: Effect of real time nitrogen management on relative growth rate between 30 to 60 DAS, 60 DAS to harvest, SPAD value at 45 DAS and Leaf chlorophyll content at threshold value of LCC of pearl millet

Treatments	Relative growth rate (g/g/day) between 30 to 60 DAS			Relative growth rate (g/g/day) between 60 DAS to harvest			SPAD value at 45 DAS			Leaf chlorophyll content at threshold value of LCC (mg/g)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	0.0773	0.0742	0.0758	0.0192	0.0204	0.0198	50.43	51.11	50.77	3.40	3.46	3.43
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0769	0.0742	0.0756	0.0189	0.0199	0.0194	53.14	53.50	53.32	3.52	3.56	3.54
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0766	0.0741	0.0754	0.0192	0.0204	0.0198	51.26	51.87	51.56	3.45	3.50	3.48
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0768	0.074	0.0754	0.0200	0.0212	0.0206	48.91	49.45	49.18	3.36	3.41	3.38
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0739	0.0742	0.0741	0.0216	0.0221	0.0218	47.55	47.44	47.49	3.30	3.35	3.32
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0729	0.0738	0.0734	0.0221	0.0226	0.0224	46.24	46.98	46.61	3.21	3.26	3.24
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0725	0.0734	0.0730	0.0224	0.0234	0.0229	45.65	45.31	45.48	3.18	3.23	3.20
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0711	0.0734	0.0723	0.0235	0.0238	0.0237	44.39	44.62	44.50	3.10	3.17	3.13
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	0.0699	0.0732	0.0716	0.0247	0.0248	0.0248	42.92	43.90	43.41	2.98	3.08	3.03
T_{10}: Control (without N application)	0.0687	0.0725	0.0706	0.0255	0.0264	0.0259	36.47	37.72	37.10	2.74	2.86	2.80
SEm±	0.0025	0.0009	0.0013	0.0027	0.0018	0.0016	2.07	2.06	1.46	0.097	0.096	0.07
C.D. at 5%	NS	NS	NS	NS	NS	NS	6.15	6.12	4.19	0.29	0.29	0.20
C.V. %	5.79	2.04	4.34	21.19	14.17	17.90	7.68	7.57	7.62	5.19	5.07	5.13
Y × T												
SEm±	0.0018			0.0023			2.07			0.10		
C.D. at 5%	NS			NS			NS			NS		

Table 5: Effect of real time nitrogen management on number of effective tillers per plant, earhead length and earhead girth of pearl millet

Treatments	Number of effective tillers per plant			Earhead length (cm)			Earhead girth (cm)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	3.23	3.30	3.26	28.51	29.06	28.79	3.28	3.32	3.30
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3.36	3.41	3.39	29.25	29.33	29.29	3.34	3.45	3.39
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3.27	3.34	3.31	28.98	29.19	29.08	3.28	3.36	3.32
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS +Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3.14	3.26	3.20	28.07	28.13	28.10	3.01	3.10	3.06
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3.03	3.11	3.07	26.74	26.94	26.84	2.90	2.97	2.94
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3.01	3.07	3.04	25.53	26.22	25.87	2.86	2.90	2.88
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.93	2.98	2.95	23.59	24.68	24.13	2.84	2.87	2.86
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.86	2.89	2.87	24.28	24.41	24.34	2.83	2.86	2.85
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	2.43	2.64	2.54	21.61	22.39	22.00	2.74	2.81	2.77
T_{10}: Control (without N application)	2.37	2.40	2.38	21.44	22.11	21.77	2.68	2.76	2.72
SEm±	0.14	0.14	0.10	1.11	1.10	0.78	0.11	0.12	0.08
C.D. at 5%	0.42	0.43	0.29	3.29	3.27	2.24	0.34	0.37	0.24
C.V. %	8.17	8.24	8.21	7.44	7.26	7.35	6.56	7.07	6.83
Y × T									
SEm±	0.14			1.10			0.12		
C.D. at 5%	NS			NS			NS		

Table 6: Effect of real time nitrogen management on grain yield, fodder yield, earhead weight and test weight of pearl millet

Treatments	Grain yield (kg/ha)			Fodder yield (kg/ha)			Earhead weight (kg/ha)			Test weight (g)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + 40 kg N/ha through Urea at 40-45 DAS	4242	4369	4305	8333	8451	8392	5778	5868	5823	8.92	8.97	8.95
T_2: 40 kg N/ha as basal + 40 kg N/ha through Urea at 25-30 DAS + Two foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4685	4742	4714	8573	8735	8654	6260	6343	6301	9.22	9.27	9.25
T_3: 40 kg N/ha as basal + 30 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	4370	4498	4434	8395	8530	8463	5999	6009	6004	9.15	9.19	9.17
T_4: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3933	4005	3969	8111	8178	8145	5768	5796	5782	8.85	8.92	8.89
T_5: 40 kg N/ha as basal + 20 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3864	3936	3900	7249	7635	7442	5568	5612	5590	8.48	8.55	8.52
T_6: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3876	3916	3896	7271	7558	7415	5440	5515	5478	8.47	8.62	8.54
T_7: 40 kg N/ha as basal + 10 kg N/ha through Urea at 25-30 DAS + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3749	3825	3787	6980	7367	7174	5293	5334	5313	8.50	8.56	8.53
T_8: 40 kg N/ha as basal + Four foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3672	3740	3706	6846	7021	6934	5256	5279	5267	8.73	8.71	8.72
T_9: 40 kg N/ha as basal + Three foliar sprays of Nano Urea 0.4% when LCC ≤ 4	3514	3591	3553	6530	6758	6644	5171	5209	5190	8.68	8.70	8.69
T_{10}: Control (without N application)	3376	3428	3402	6260	6402	6331	4710	4854	4782	8.30	8.33	8.32
SEm±	244	258	178	431	359	280	265	263	187	0.30	0.28	0.21
C.D. at 5%	725	767	510	1281	1065	805	787	781	536	NS	NS	NS
C.V. %	10.76	11.16	10.97	10.02	8.10	9.08	8.30	8.16	8.23	6.05	5.55	5.80
Y × T												
SEm±	251			397			264			0.29		
C.D. at 5%	NS			NS			NS			NS		

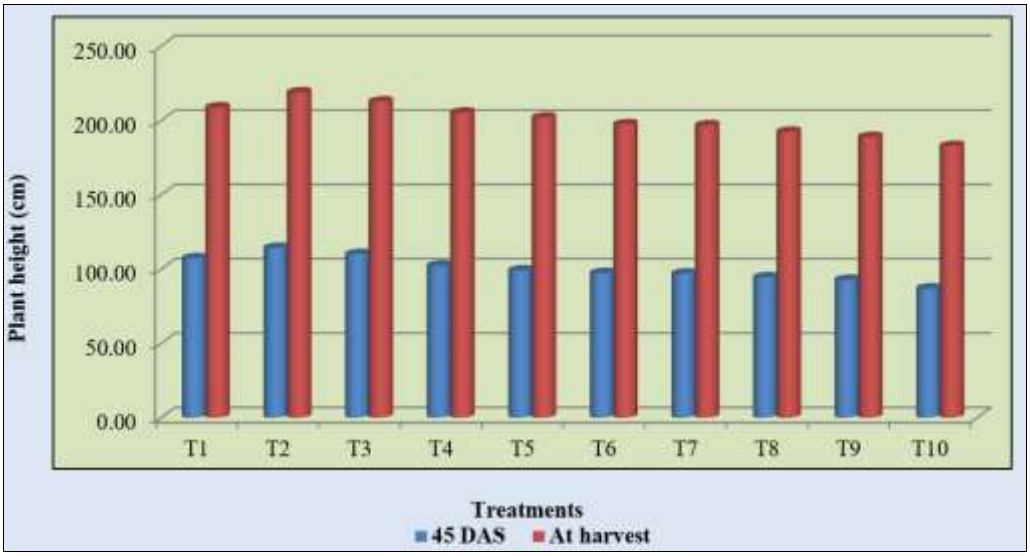

Fig 3: Effect of real time nitrogen management on plant height at 45 DAS and at harvest of pearl millet

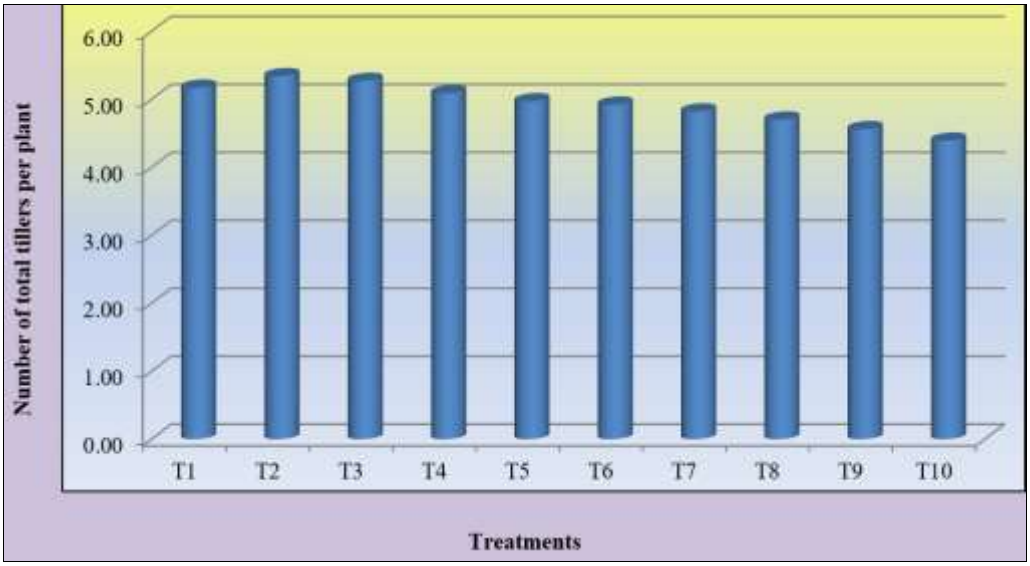

Fig 4: Effect of real time nitrogen management on number of total tillers per plant of pearl millet

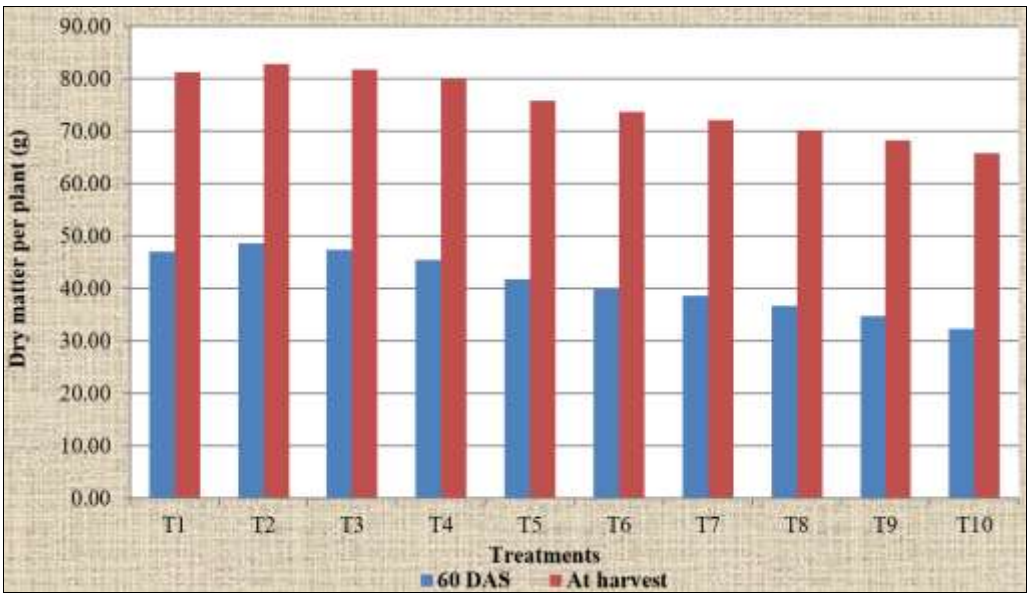

Fig 5: Effect of real time nitrogen management on dry matter per plant at 60 DAS and at harvest of pearl millet

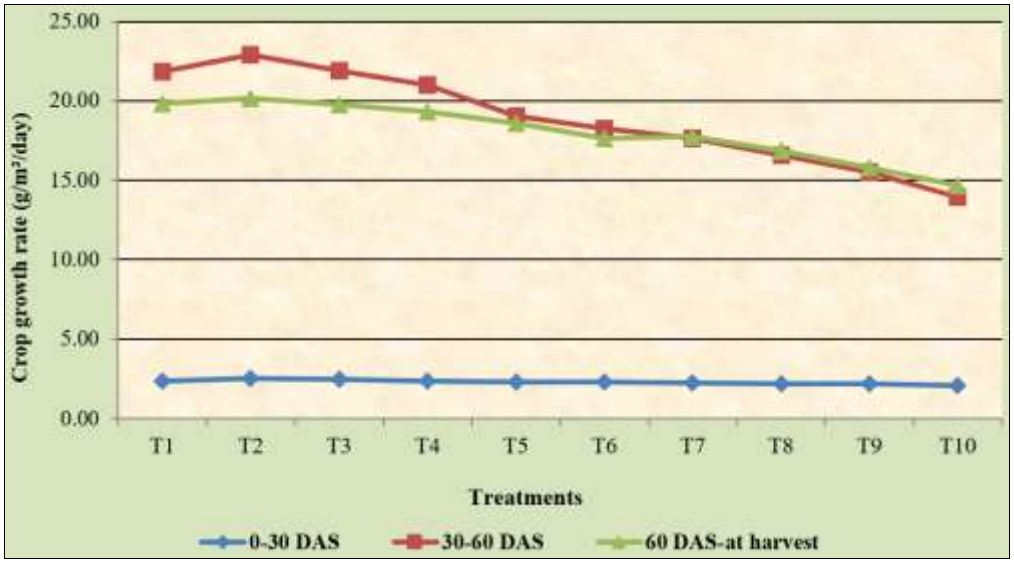

Fig 6: Effect of real time nitrogen management on crop growth rate between 0-30 DAS, 30-60 DAS and 60 DAS-at harvest of pearl millet

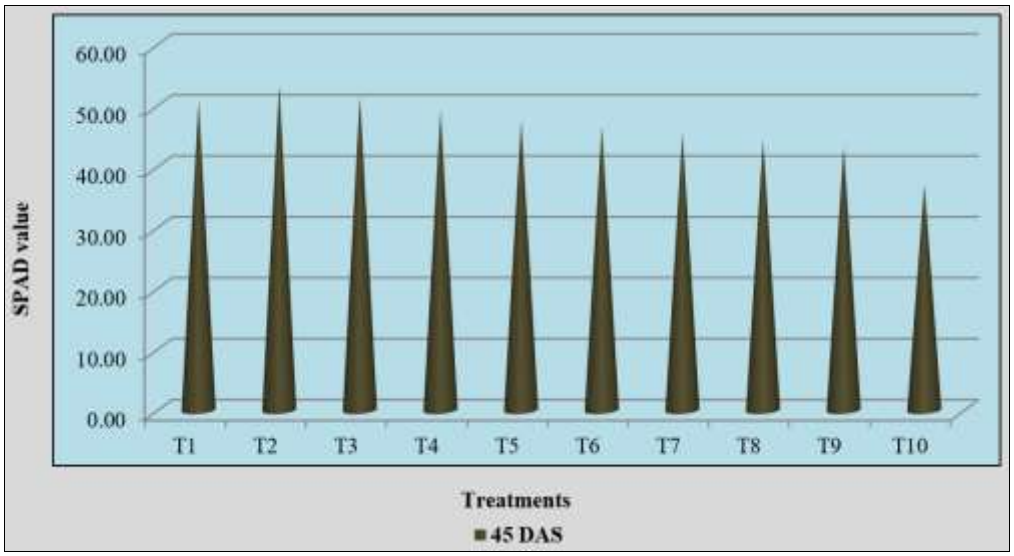

Fig 7: Effect of real time nitrogen management on SPAD value at 45 DAS of pearl millet

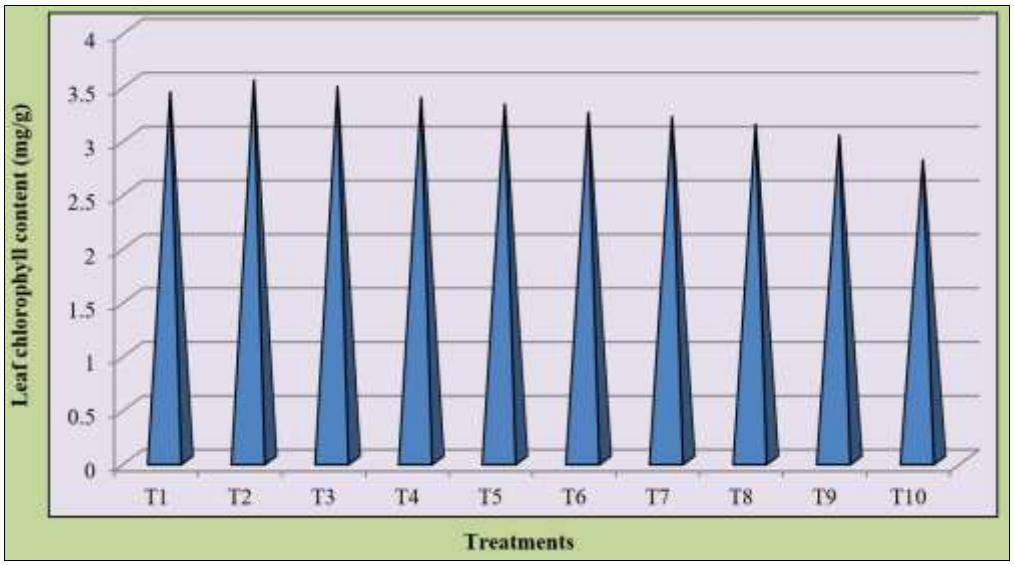

Fig 8: Effect of real time nitrogen management on leaf chlorophyll content at threshold value of LCC of pearl millet

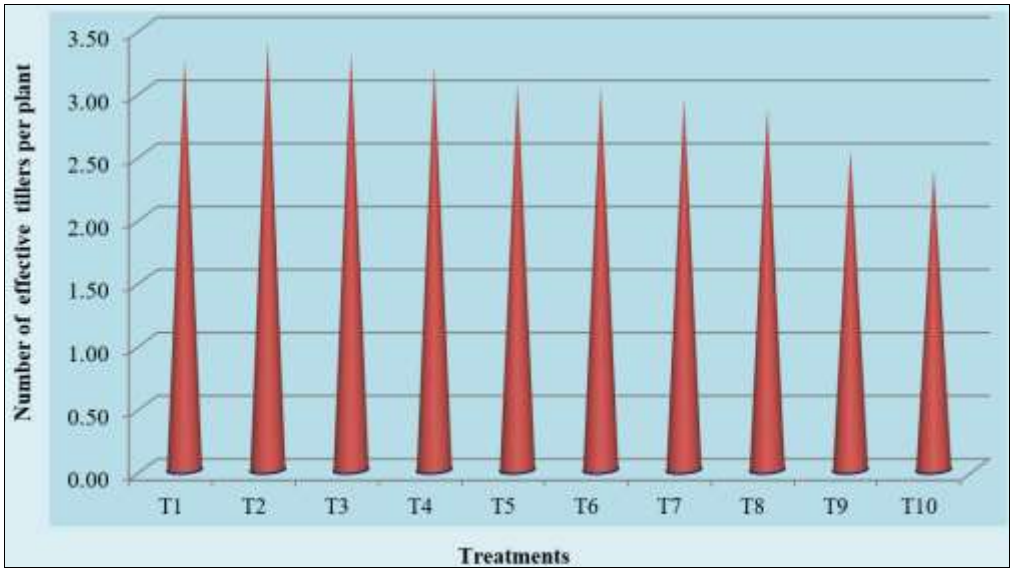

Fig 9: Effect of real time nitrogen management on number of effective tillers per plant of pearl millet

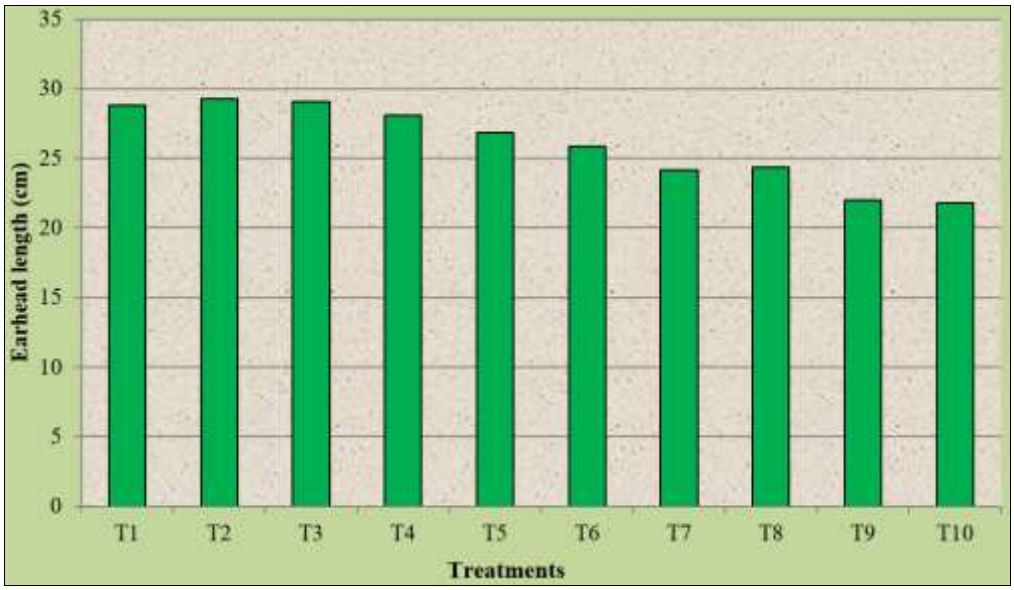

Fig 10: Effect of real time nitrogen management on earhead length of pearl millet

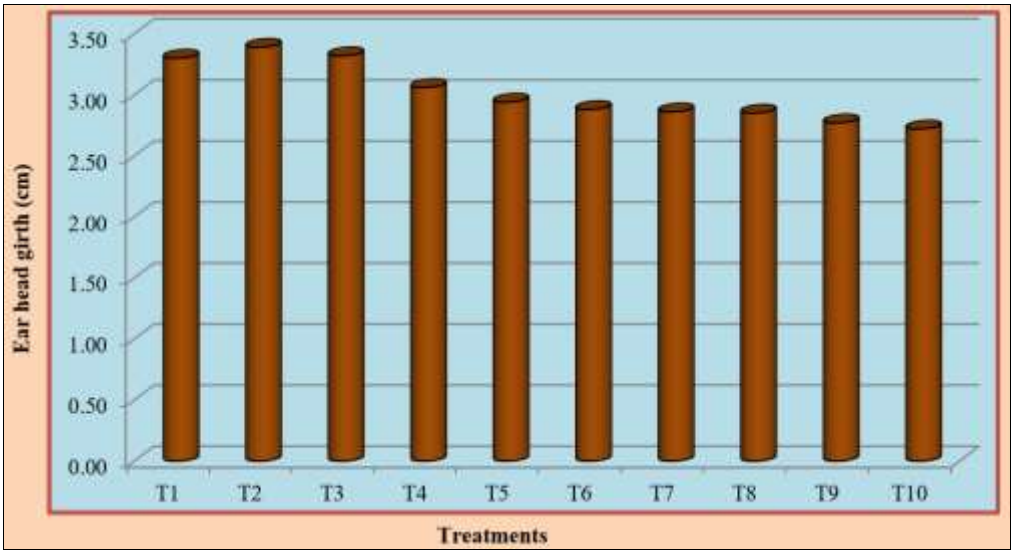

Fig 11: Effect of real time nitrogen management on earhead girth of pearl millet

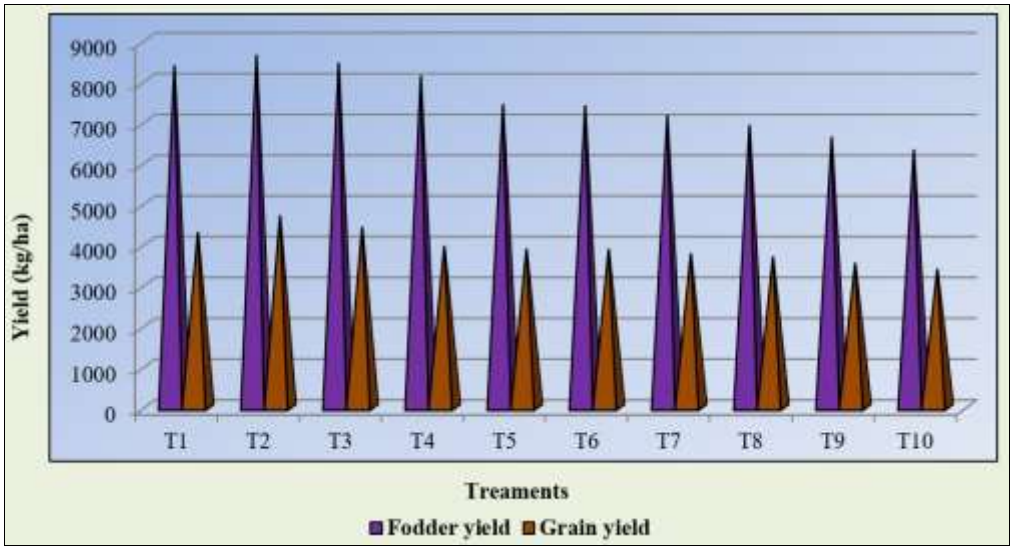

Fig 12: Effect of real time nitrogen management on grain and fodder yield of pearl millet

Conclusion

On the basis of two-year field experimentation, it can be concluded that higher growth, grain yield, fodder yield, quality, net returns and nitrogen use efficiency in summer pearl millet can be obtained by the application of 40 kg N/ha as basal + 40 kg N/ha through urea at 25-30 DAS + two foliar sprays of nano urea 0.4% when LCC ≤ 4.

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