Original Research Article

Influenceof Foliar Application of Nitrogen Through Urea and Nano Urea on Morphophysiological and Yield in Foxtail Millet (*Setaria italica L.*)

ABSTRACT

A field experiment was conducted at Collegeof Agriculture Nagpur, during *Kharif* 2023 in randomized blocked design (RBD) with PDKV Yashshree (BFTM-82) variety, at Research FarmofAgriculturalBotanySection,Collegeof Agriculture Nagpur, with three replications andeight treatments. The results revealed that the best treatment 25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1} (T_8) applied at tillering and pre-flowering stage was significantly superior as compared to other treatments which shows the highest value in morpho-physiological*viz.,* Plant height (163.00 cm) at 80 DAS, days to 50% flowering (57.00), days to maturity (87.00), RGR (0.095 g^{-1} dm^{-2} day^{-1}) at 60-80 DAS and CGR (0.82 g^{-1} cm^{-2} day^{-1}) at 60-80 DAS and yield parameters *viz.,*No. of panicle hill^{-1} (4.90), Panicle length (24.37 cm), No. of spikelet panicle^{-1} (66.07), Grain yield kg plot^{-1} (1.30),Grain yield kg ha^{-1} (1421.78),Harvest index (63.50%) of foxtail millet.

Key words: Foxtail millet, Nano-urea, Morpho-physiological, Yield.

1. INTRODUCTION

Foxtail millet (*Setaria italica L.)*is an important small millet crop which has been cultivated from ages all over the world. It is believed to be originated in North China, and it was domesticated more than 8,700 years ago(Pan *et al.,* 2018)[1].Recently, small millets are reevaluated as 'nutri-cereals' and climate resilient crops because of their ability to withstand under unfavorable consequences of climate change facilitating food and nutritional security for rapidly developing population, especially in resource-poor and rainfed areas (Brahmachari *et al*., 2019 [2]; Prasanna Kumar *et al.*, 2019 [3]). Among various small millets, foxtail millet (*Setaria italica L.)*commonly known as Kangni in Hindi and kang or rala in Marathi is the most important crop in terms of its higher production with wider adaptability and potential of greater productivity. Foxtail millet is a hardy crop that can grow in a variety of climates and soils, but it is most commonly grown in semi-arid regions where other crops may not thrive. These small, yellow grains can be found in many parts of the world, including Asia, Europe, and North America. It is also grown in some parts of Africa and South America. In Asia, it is particularly popular in countries such as China, Japan, and India. In India, cultivation of foxtail millet is mainly confined to the southern states of Andhra Pradesh, Karnataka and Tamil Nadu.

Among different small millets, foxtail millet (*Setaria italica L.*) has the heritage of Asian origin and was domesticated in central China during ancient period (Miller *et al.*2016)[4]. Like other millets it belongs to Poaceae family and a member of the subfamily Panicoideae. Foxtail millet is nutrient rich and each 100 g of edible portion contains fibre 2.4 g, protein 12.3 g, carbohydrates 60.9 g, fat 4.3 g, calcium 31 mg, iron 2.8 mg, phosphorus 290 mg, minerals 3.3 g and food energy 331 K Cal (Banerjee and Maitra, 2020)[5].Foxtail millet is mainly cultivated in dry regions of India as rainfed crop as the crop shows great tolerance under drought conditions. In India, the cultivation of foxtail millet is confined southern states, namely, to Andhra Pradesh, Karnataka, Tamil Nadu and Telengana, also to some extent grown in Bihar, Uttar Pradesh and Uttarakhand. The average productivity of small millets including foxtail millets is very less.

To achieve higher productivity, adequate supply of nutrients through a right source could be an appropriate approach. Among the nutrients, the physiological role of nitrogen attributes to enhance crop productivity (Chavan *et al*., 2018[6]; Ramya *et al.*, 2020[7]).However, soil applied nitrogenous fertilizers were influenced by various environmental factors and thereby limits its efficiency in nutrient use (Van Eerd *et al*., 2018) [8]. Consequently, resulted in the appearance of acute deficiency symptoms adversely affecting the crop growth and development. In this case supplementation of nitrogen, through foliar spray could be most efficient and appropriate strategy (Liu and Lal, 2015) [9]. In an experiment, Reddy *et al.* (2018) [10] found statistically significant increase in the yield attributes of finger millet upon application of urea @ 2 per cent. However, with the recent introduction of nano urea by Indian farmers fertilizer cooperative (IFFCO) increased the scope of nano-technology in agriculture. The large surface area and small particle size of nano fertilizers attribute to increase its availability (Lu *et al.*, 2016) [11]. However, research evidence supporting its ability in comparison to the macro-scaled urea on Foxtail millet is inadequate.

Keeping in view the aforesaid facts, the present investigation was carried out to study the influence of foliar application of nitrogen through urea and nano urea on morphophysiological and yield in foxtail millet.

2. MATERIALS AND METHODS

The research work on “Influence of foliar application of nitrogen through urea and nano urea on morphophysiological and yield in foxtail millet (*Setaria italica L.*)” A field experiment was conducted at Research farmofAgriculturalBotanysection,CollegeofAgriculture, Nagpur during *Kharif* 2023 with three replications andeight treatments. The treatments included in this experiment were (T_1) 0 N kg ha^{-1} (Control), (T_2) 25 N kg ha^{-1} as basal dose, (T_3) 50 N kg ha^{-1} (RDF), (T_4) 25 N kg ha^{-1} + two spray of @ 1% urea, (T_5) 25 N kg ha^{-1} + two spray @ 2% urea, (T_6) 25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}, (T_7) 25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}, (T_8) 25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}.Experiment was laid out in RBD design. Sowing was done by dibbling (direct sowing) method on dated31st July 2023 at a spacing of 45 cm x 10 cm. Thereafter, all theinterculturaloperationsweredoneasandwhenrequired. The recommended dose of N will be given as per treatments, however, P and K is 25:25 kg P: K ha^{-1} was applied in all treatments at the time of sowing.

3. RESULTS AND DISCUSSION

3.1 Morpho-physiological parameters

3.1.1 Plant height (cm)

The data presented in table 1, indicated that plant height at 40 DAS were found statistically significant. At 40 DAS, the range of plant height was 73.33 cm to 134.00 cm. Significantly highest plant height (134.00 cm) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_3 (50 N kg ha^{-1} (RDF)) (132.08 cm), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (129.67 cm), T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (117.67 cm) and treatment T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (109.67 cm) when compared with treatment T_1 (control). And treatments T_2 (25 N kg ha^{-1} as basal dose) (88.08 cm), T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (97.58 cm). Lowest plant height (73.33 cm) was recorded in treatments T_1 (control).

At 60 DAS, the range of plant height was 96.67 cm to 159.00 cm. Significantly highest plant height (159.00 cm) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_3 (25 N kg ha^{-1} (RDF)) (157.08 cm), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (154.67 cm), T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (136.00 cm) and treatment T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (134.67 cm) when compared with treatment T_1 (control). And treatments T_2 (25 N kg ha^{-1} as basal dose) (111.74 cm), T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (122.58 cm). Lowest plant height (96.67 cm) was recorded in treatments T_1 (control).

At 80 DAS the range of plant height was 99.73 cm to 163.00 cm. Significantly highest plant height (163.00 cm) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_3 (50 N kg ha^{-1} (RDF)) (160.75 cm), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (157.29 cm), when compared with treatment T_1 (control). And treatments T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (138.73 cm), T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (138.41 cm), T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (125.96 cm) and treatment T_2 (25 N kg ha^{-1} as basal dose) (116.67 cm). Lowest plant height (99.73 cm) recorded in treatments T_1 (control).The study found that applying nano-urea via foliar spray increased plant height, especially when combined with a basal fertilizer dose. This boost in plant stature likely results from improved nutrient uptake, which enhances cell division and protein synthesis. These results are consistent with Benzon *et al.* (2015) [12], who also observed increased plant height with nano-urea, even at lower application rates, when used with traditional fertilizers.

3.1.2 Days to 50% flowering

The data presented in table 1, indicated that days to 50% flowering of PDKV Yashshree (BFTM-82) significant difference was found in treatments. The range of days to 50% flowering recorded was 43.33-57.00 days. Late number of days to 50% flowering (57.00) was recorded in treatment T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) while early number of days to 50% flowering (43.33) was recorded in treatment T_1 (control), preceded by treatment T_3 (50 N kg ha^{-1} (RDF)) (54.67), treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (47.67), T_2 (25 N kg ha^{-1} as basal dose) (46.00), T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (53.67) and treatments T_7 (25 N kg ha^{-1}

+ two spray of nano urea @ 3 ml L^{-1}) (56.67), T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) (56.00). It could be because plants have increased strength when nano urea is sprayed during the panicle initiation period, which results in early flowering. similar results were recorded by Midde *et al*. (2022)[13].

3.1.3 Days to Maturity

The data presented in table1, indicated that days to maturity of PDKV Yashshree (BFTM-82) significant difference was found in treatments. The range of days to maturity recorded was 69.00-87.00 days. Late number of days to maturity (87.00) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) while early number of days to maturity (69.00) was recorded in treatment T_1 (control), preceded by treatment T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (85.67), T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (85.33), T_3 (50 N kg ha^{-1} (RDF)) (82.33), T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (80.67) and treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (78.67), T_2 (25 N kg ha^{-1} as basal dose) (75.00).It could be because of the availability of nitrogen to the plants more efficiently than conventional urea. This increased nitrogen availability can accelerate plant growth, leading to earlier flowering and grain filling. The rapid uptake and utilization of nano urea by the plant can result in faster physiological development, thereby shortening the crop's maturation period. However, similar results were reported by Yadav (2023)[14].

3.1.4Leaf area $plant^{-1}$ (cm^2)

The data presented in table 1,at 40 DAS indicated non-significant variation. At 40 DAS, the range of leaf area was 523.70 cm^2 to 669.73 cm^2. But numerically highest leaf area (669.73 cm^2) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (662.81 cm^2), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (644.90 cm^2), when compared with treatment T_1 (control). Lowest leaf area (523.70 cm^2) was recorded in treatment T_1 (control).

At 60 DAS was found to be statistically non-significant. At 60 DAS, the range of leaf area was 590.36 cm^2 to 769.73 cm^2. The numerically highest leaf area (769.73 cm^2) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (762.81 cm^2) and treatment T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (744.90 cm^2), when compared with treatment T_1 (control). Lowest leaf area (590.36 cm^2) was recorded in treatment T_1 (control).

At 80 DAS was found to be statistically non-significant. At 80 DAS, the range of leaf area was 530.86 cm^2 to 675.63 cm^2. The numerically highest leaf area (675.63 cm^2) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (668.32 cm^2) and treatment T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (652.80 cm^2), when compared with treatment T_1 (control). Lowest leaf area (530.86 cm^2) was recorded in treatment T_1 (control). This might be due to providing a more efficient and readily available source of nitrogen, which is essential for leaf development. Nano urea's smaller particles allow for quicker absorption and utilization by the plant, leading to enhanced nitrogen metabolism. This, in turn, promotes vigorous cell division and expansion in the leaves, resulting in larger, healthier leaves with greater surface area. A larger leaf area improves the plant's ability to capture sunlight, enhancing photosynthesis and overall growth, which contributes to better crop performance and higher yield potential.

3.1.5Leaf area index (LAI)

The data presented in table 1,at 40 DAS was found to be statistically non-significant. The range of leaf area index was 1.16 to 1.48. The numerically highest leaf area index (1.48) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (1.47), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (1.43), when compared with treatment T_1 (control). Lowest leaf area index (1.16) was recorded in treatment T_1 (control).

At 60 DAS was found to be statistically non-significant. The range of leaf area index was 1.31 to 1.71. The numerically highest leaf area index (1.71) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (1.69), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (1.65), when compared with treatment T_1 (control). Lowest leaf area index (1.31) was recorded in treatment T_1 (control).

At 80 DAS was found to be statistically non-significant. The range of leaf area index was 1.17 to 1.50. The numerically highest leaf area index (1.50) was recorded in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by treatment T_3 (50 N kg ha^{-1} (RDF)) (1.48), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (1.45), when compared with treatment T_1 (control). Lowest leaf area index (1.17) was recorded in treatment T_1 (control).It has been demonstrated that using nano-urea spray has a major impact on the rice leaf area index (LAI). Higher LAI is the outcome of enhanced nutrient uptake and utilisation brought on by nano-urea spray, as per studies by Sharma *et al.* (2022)[15]. The nanoscale formulation ensures better nutrient absorption and penetration via leaves, promoting overall canopy development and leaf growth.

3.1.6Relative growth rate (g^{-1} dm^{-2} day^{-1})

The data presented in table 1, indicated that relative growth rate (g^{-1} dm^{-2} day^{-1}) between 40 DAS to 60 DAS was found statistically significant. Significantly highest relative growth rate (0.074 g^{-1} dm^{-2} day^{-1}) was noted in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (0.070 g^{-1} dm^{-2} day^{-1}) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (0.067 g^{-1} dm^{-2} day^{-1}), T_3 (50 N kg ha^{-1} (RDF)) (0.066 g^{-1} dm^{-2} day^{-1}), when compared with treatment T_1 (control). Lowest relative growth rate (0.045 g^{-1} dm^{-2} day^{-1}) was recorded in treatment T_1 (control).

At 60 DAS to 80 DAS was found statistically significant. Significantly highest relative growth rate (0.095 g^{-1} dm^{-2} day^{-1}) was noted in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments followed by T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (0.094 g^{-1} dm^{-2} day^{-1}) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (0.084 $g^{-1}$$dm^{-1}$ day^{-1}), T_3 (50 N kg ha^{-1} (RDF)) (0.081 g^{-1} dm^{-2} day^{-1}), when compared with treatment T_1 (control). Lowest relative growth rate (0.069 g^{-1} dm^{-2} day^{-1}) was recorded in treatment T_1 (control).

3.1.7Crop growth rate (g^{-1} cm^{-2} day^{-1})

The data presented in table1,indicated that crop growth rate (g^{-1} cm^{-2} day^{-1}) between 40 DAS to 60 DAS was found statistically significant. Significantly highest crop growth rate (0.79 g^{-1} cm^{-2} day^{-1}) was noted in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (0.77 g^{-1} cm^{-2} day^{-1}) and T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (0.65 g^{-1} cm^{-2} day^{-1}), when compared with treatment T_1 (control). Lowest crop growth rate

(0.47 g^{-1} cm^{-2} day^{-1}) was recorded in treatment T_1 (control). and treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (0.57 g^{-1} cm^{-2} day^{-1}), treatment T_2 (25 N kg ha^{-1} as basal dose) (0.55 g^{-1} cm^{-2} day^{-1}).

The data presented in table 1, indicated that crop growth rate (g^{-1} cm^{-2} day^{-1}) between 60 DAS to 80 DAS was found statistically non-significant. Numerically highest crop growth rate (0.82 g^{-1} cm^{-2} day^{-1}) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (0.77 g^{-1} cm^{-2} day^{-1}) and T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (0.67 g^{-1} cm^{-2} day^{-1}), and treatment T_3 (50 N kg ha^{-1} (RDF), T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (0.65 g^{-1} cm^{-2} day^{-1}), treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (0.64 g^{-1} cm^{-2} day^{-1}), T_2 (25 N kg ha^{-1} as basal dose) (0.58 g^{-1} cm^{-2} day^{-1}), when compared with treatment T_1 (control). Lowest crop growth rate (0.48 g^{-1} cm^{-2} day^{-1}) was recorded in treatment T_1 (control).Results could be explained by the significant part N plays in the production of auxin, which is necessary for cell division and the elongation of internodes. N's crucial function in the activation of several enzymes, including those needed for the CO_2 absorption pathway and chlorophyll biosynthesis, is in addition to this. However, similar results were reported by Gewaily *et al.* (2019)[16].

3.2Yieldcontributing parameters

3.2.1 1000 grain weight (g)

The data presented in table 2, indicated that 1000 grain weight (g) was found statistically non-significant. Numerically highest 1000 grain weight (2.80g) was registered in treatment T_3 (50 N kg ha^{-1} (RDF)), T_5 (25 N kg ha^{-1} + two spray @ 2% urea), and treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) followed by T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (2.73 g) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (2.67 g), T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (2.60 g), and treatment T_2 (25 N kg ha^{-1} as basal dose) (2.57 g), when compared with treatment T_1 (control). Lowest 1000 grain weight (2.50 g) was recorded in treatment T_1 (control).may be due to the reason that nano fertilizers promote the plant to absorb the water of soil and nutrients, then the photosynthesis is improved (Wu, 2013)[17].

3.2.2 Number of panicles $hill^{-1}$

The data presented in table 2.Indicated that number of panicles hill^{-1} was found statistically significant. Significantly highest number of panicles hill^{-1} (4.90) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (4.73) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (4.70), T_3 (50 N kg ha^{-1} (RDF)) (4.50), T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (4.07), and treatment T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (4.03), when compared with treatment T_1 (control). Lowest number of panicles hill^{-1} (2.40) was recorded in treatment T_1 (control).The foliar application of nano fertilizers improved the plant's ability to absorb and translocate nutrients and created a hospitable environment for the crop. This increased cell division, meristematic activity and stimulation of cell elongation in plants ultimately led to a higher number of panicles hill^{-1}, similar results were reported by Rajput *et al.* (2022)[18].

3.2.3 Panicle length (cm)

The data presented in table 2. Indicated that length of panicle (cm) was found statistically significant. Significantly highest panicle length (24.37 cm) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (23.13 cm), T_3 (50 N kg ha^{-1} (RDF)) (22.90 cm) and T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (21.60 cm), and treatment T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (18.63 cm), when compared with treatment T_1 (control). Lowest panicle length (15.40 cm) was recorded in treatment T_1 (control).In present study the panicle length is increased with foliar application of nano urea. This may be due the foliar application of nano urea at their critical stage (tillering and panicle initiation), this may lead to supply sufficient amount of nitrogen. Nitrogen enhances the cell elongation, activity of meristematic cells and also increases grain formation.

3.2.4Number of spikelet panicle^{-1}

The data presented in table 2. Indicated that number of spikelet panicle^{-1} was found statistically significant. Significantly highest number of spikelet panicle^{-1} (66.07) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_5 (25 N kg ha^{-1} + two spray @ 2%

urea) (62.83), T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (60.40) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (56.33), when compared with treatment T_1 (control). Lowest number of spikelet panicle^{-1}and number of tillers hill^{-1}(45.30) was recorded in treatment T_1 (control).

3.2.5Grain yield kg plot^{-1}

The data presented in table 2. Indicated that grain yield kg plot^{-1} was found statistically significant. Significantly highest grain yield kg plot^{-1} (1.30 kg plot^{-1}) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_3 (50 N kg ha^{-1} (RDF)) (1.29 kg plot^{-1}) and T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (1.27 kg plot^{-1}), T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (1.22 kg plot^{-1}) and T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (1.13 kg plot^{-1}) and treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (1.10 kg plot^{-1}), when compared with treatment T_1 (control). Lowest grain yield kg ha^{-1} (0.82 kg plot^{-1}) was recorded in treatment T_1 (control).

3.2.6Grain yield kg ha^{-1}

The data presented in table 2. Indicated that grain yield kg ha^{-1} was found statistically significant. Significantly highest grain yield kg ha^{-1} (1421.78 kg ha^{-1}) was registered in treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_3 (50 N kg ha^{-1} (RDF)) (1414.47 kg ha^{-1}) and T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (1388.89 kg ha^{-1}), T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (1334.06 kg ha^{-1}) and T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (1235.38 kg ha^{-1}) and treatment T_4 (25 N kg ha^{-1} + two spray of @ 1% urea) (1206.14 kg ha^{-1}), when compared with treatment T_1 (control). Lowest grain yield kg ha^{-1} (895.47 kg ha^{-1}) was recorded in treatment T_1 (control). Result could be enhanced efficiency in providing nitrogen, a critical nutrient for plant growth. Nano urea particles are smaller and more readily absorbed by the plant, leading to improved nitrogen use efficiency. This ensures that the millet plants receive an optimal amount of nitrogen, promoting vigorous growth, better tillering, and more robust grain development. As a result, the plants can produce more grains of higher quality, ultimately leading to increased yield. However, similar results were reported by Hayyawi *et al.* (2018)[19].

3.2.7 Harvest index (%)

The data presented in table 2. Indicated that harvest index (%) was found statistically significant. Statistically highest harvest index (63.50%) was registered in treatment T_3 (50 N kg ha^{-1} (RDF)) which was found significantly superior over all the remaining treatments. However, it was at par with treatments T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1}) (60.87%) and T_7 (25 N kg ha^{-1} + two spray of nano urea @ 3 ml L^{-1}) (60.15%), T_5 (25 N kg ha^{-1} + two spray @ 2% urea) (58.51%) and T_6 (25 N kg ha^{-1} + two spray of nano urea @ 2 ml L^{-1}) (56.25%) and treatment T_2 (25 N kg ha^{-1})(54.43%), when compared with treatment T_1 (control).Could be the plant absorbs and utilizes nitrogen more effectively. This leads to enhanced photosynthesis, stronger root development, and improved nutrient distribution, allowing the plant to allocate more energy towards grain production rather than excessive vegetative growth. Consequently, the proportion of grain yield relative to total biomass increases, resulting in a higher harvest index. Similar results were reported by Karanjikar *et al.* (2024) [20].

CONCLUSION

Based on results, treatment T_8 (25 N kg ha^{-1} + two spray of nano urea @ 4 ml L^{-1})foliar application at tillering and pre-flowering stage was found significantly superior in enhancing morpho-physiologicalparameters like,plant height (cm), Days to 50% flowering, Days to maturity, RGR and CGR, yield and yield contributing characters like,Number of panicles $hill^{-1}$,Panicle length (cm), No. of spikelet $panicle^{-1}$,Grain yield kg $plot^{-1}$,Grain yield kg ha^{-1}, Harvest Index (%) and B : C ratio, Whereas, treatment T_3 (50 N kg ha^{-1} (RDF)) found at par.

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Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.

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3.

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Table 1. Effect of nitrogen through nano urea on Morpho-physiological parameters in foxtail millet

Treatments	Plant height (cm)			Days to 50% flowering	Days to maturity	Leaf area plant^{-1} (cm^2)			Leaf area index (LAI)			Relative growth rate (g^{-1} dm^{-2} day^{-1})		Crop growth rate (g^{-1}cm^{-2} day^{-1})	
	40 DAS	60 DAS	80 DAS			40 DAS	60 DAS	80 DAS	40 DAS	60 DAS	80 DAS	40-60 DAS	60-80 DAS	40-60 DAS	60-80 DAS
T1 (Control)	73.33	96.67	99.73	43.33	69.00	523.70	590.36	530.86	1.16	1.31	1.17	0.045	0.069	0.47	0.48
T2 (25 N kg ha^{-1})	88.08	111.74	116.67	46.00	75.00	557.66	624.32	563.59	1.23	1.38	1.25	0.059	0.077	0.55	0.58
T3 (50 N kg ha^{-1} RDF)	132.08	157.08	160.75	54.67	82.33	662.81	762.81	668.32	1.47	1.69	1.48	0.066	0.081	0.62	0.65
T4 (25 N kg ha^{-1}+ two spray of @ 1% urea)	97.58	122.58	125.96	47.67	78.67	560.75	727.42	566.69	1.24	1.61	1.25	0.061	0.079	0.57	0.64
T5 (25 N kg ha^{-1}+ two spray of @ 2% urea)	117.67	136.00	138.73	53.67	80.67	598.19	731.52	603.27	1.32	1.62	1.34	0.062	0.083	0.65	0.67
T6 (25 N kg ha^{-1}+ two spray of nano urea @ 2 ml L^{-1})	109.67	134.67	138.41	57.00	85.33	565.47	732.14	567.81	1.25	1.62	1.26	0.067	0.084	0.63	0.65
T7 (25 N kg ha^{-1}+ two spray of nano urea @ 3 ml L^{-1})	129.67	154.67	157.29	56.67	85.67	644.90	744.90	652.80	1.43	1.65	1.45	0.070	0.094	0.77	0.77
T8 (25 N kg ha^{-1}+ two spray of nano urea @ 4 ml L^{-1})	134.00	159.00	163.00	56.00	87.00	669.73	769.73	675.63	1.48	1.71	1.50	0.074	0.095	0.79	0.82
F-test	**Sig**	**Sig**	**Sig**	**Sig**	**Sig**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**Sig**	**Sig**	**Sig**	**NS**
SE (m)±	**10.96**	**11.04**	**7.96**	**2.51**	**1.87**	**45.59**	**52.60**	**37.65**	**0.10**	**0.11**	**0.08**	**0.004**	**0.006**	**0.06**	**0.06**
CD at 5%	**33.26**	**33.48**	**21.15**	**7.61**	**5.68**	**-**	**-**	**-**	**-**	**-**	**-**	**0.01**	**0.02**	**0.17**	**-**

Table 2. Effect of nitrogen through nano urea on yield contributing parameters infoxtail millet

Treatments	Test weight (g)	No.of panicle hill^{-1}	Panicle length (cm)	No. of spikelet panicle^{-1}	Grain yield kg plot^{-1}	Grain yield kg ha^{-1}	Harvest index (%)	B:C ratio
T1 (Control)	2.50	2.40	15.40	45.30	0.82	895.47	45.20	1:1.11
T2 (25 N kg ha^{-1})	2.57	3.40	16.97	50.07	1.04	1136.70	54.43	1:1.34
T3 (50 N kg ha^{-1} RDF)	2.80	4.50	22.90	54.93	1.29	1414.47	63.50	1:1.59
T4 (25 N kg ha^{-1}+ two spray of @ 1% urea)	2.60	4.07	17.77	52.40	1.10	1206.14	52.74	1:1.40
T5 (25 N kg ha^{-1}+ two spray of @ 2% urea)	2.80	4.03	21.60	62.83	1.13	1235.38	58.51	1:1.43
T6 (25 N kg ha^{-1}+ two spray of nano urea @ 2 ml L^{-1})	2.67	4.70	18.63	56.33	1.22	1334.06	56.25	1:1.50
T7 (25 N kg ha^{-1}+ two spray of nano urea @ 3 ml L^{-1})	2.73	4.73	23.13	60.40	1.27	1388.89	60.15	1:1.56
T8 (25 N kg ha^{-1}+ two spray of nano urea @ 4 ml L^{-1})	2.80	4.90	24.37	66.07	1.30	1421.78	60.87	1:1.59
F-test	**NS**	**Sig**	**Sig**	**Sig**	**Sig**	**Sig**	**Sig**	**-**
SE (m)±	**0.15**	**0.43**	**1.90**	**3.42**	**0.08**	**92.67**	**3.01**	**-**
CD at 5%	**-**	**1.30**	**5.76**	**10.36**	**0.26**	**281.10**	**9.13**	**-**