*Original Research Article*

Effect of foliar application of nano and conventional urea on nitrogen uptake and use efficiency in ragi

**Abstract**

A field trial was carried out at Agricultural and Horticultural Research Station, Bavikere, Shivamogga, India, during Late *Kharif* 2022. The experiment was laid out in RCBD with eleven treatments and three replications. The treatments consists of absolute control (T1), recommended dose of fertilizer (T2), 50 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T3), 75 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T4), 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5), 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6), 50 per cent RDN + two sprays of 2 per cent urea fertilizer at 30 & 45 DAT (T7), 75 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T8), 75 per cent RDN + two sprays of 2 per cent urea fertilizer at 30 & 45 DAT (T9), 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10), four sprays of 0.4 per cent nano urea fertilizer at 15, 30, 45 & 60 DAT (T11). The results showed that the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT recorded higher total dry matter accumulation (46.75 g hill-1), absolute growth rate (0.64 g day-1), crop growth rate (21.39 g m-2 day-1), grain yield (3812 kg ha-1) and total nitrogen uptake (89.60 kg ha-1), which was statistically on par with the T10 and T5. Treatment T5 recorded higher nitrogen use efficiency (48.41 %) compared to T2 (36.41 %).

***Keywords:*** *Nano urea; Growth; Yield; Nitrogen uptake*

1. **Introduction**

Millets are minor cereals of the grass family, Poaceae. They are small

seeded, annual cereal grasses, many of which are adapted to tropical and arid

climates and are characterized by their ability to survive in less fertile soil

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Finger millet is an important small millet crop grown in India and has the pride of place in having highest productivity among millets. It is also known as ragi, African millet and Bird’s foot millet and an important staple food crop in part of eastern and central Africa and India. Finger millet, scientifically known as *Eleusine coracana* L. Gaertn is a resilient and nutritious crop that thrives in India. It is one of the most important staple food crops in various parts of central and eastern Africa and India. It is characterized by its small, finger-like grains and is a crucial staple food in Indian agriculture due to its adaptability and nutritional value. It occupies an area of 1.21 m ha with a production of 1.70 m t and average productivity of 1396 kg ha-1 (Anon, 2022) in India. It is a rich source of calcium (344 mg/100g), phosphorus (283 mg/100g) and iron (3.9 mg/100g) as compared to all other cereals and millets (Gopalan *et al*., 2009) [6]. It has distinguished health beneficial properties such as anti-diabetic, anti-diarrhea, anti-inflammatory, anti-microbial and antioxidant properties (Shobana *et al*., 2013) [19].

Nutrients are essential for maintaining and improving crop growth and development. When the nutrient application is not synchronized with crop demand, losses from the soil-plant system are large, leading to low fertilizer use efficiency. Among different nutrients, Nitrogen is an integral part of chlorophyll and involved in the formation of proteins, nucleic acids, growth hormones and vitamins and. An adequate supply of nitrogen is associated with vigorous vegetative growth and dark green colour (Kantwa and Yadav, 2022) [8]. The soil applied nitrogen through urea fertilizers undergoes transformation processes such as biological nitrogen fixation, humus mineralization, immobilization, nitrification and volatilization. Because of these transformation processes, nitrogen management is extremely complicated, making it challenging to increase nitrogen use efficiency.

Several technologies have been proposed in recent years to increase the nitrogen use efficiency by crops. Among these, the multidisciplinary study area of nanotechnology is promising and opens up a wide range of potential in the field of agriculture (Qureshi *et al*., 2018) [16]. The term "nano" is derived from the Greek word for "dwarf," or one billionth of a metre and particles which are smaller than 100 nm are termed nanoparticles (Thakkar *et al*., 2010) [22]. Nano fertilizers when used as foliar application have the ability to enter through the porous cell wall of plant cells due to their minute particle size (< 50 nm) allowing for higher absorption compared to conventional fertilizers (Benzon *et al.*, 2015) [3]. Nano fertilizers are nanoparticles that employ nanotechnology to boost nutrients and increase their use efficiency (Khalid *et al.,* 2022) [10]. Nano urea particles have large surface area and particle size, less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano fertilizer which leads to more penetration and uptake of the nutrient and thus results in high nutrient use efficiency (Mehta and Bharat, 2019) [14]. So far, several researchers have found the beneficial effect of nano urea on different crops, but the use of nano urea on finger millet is scarce. Hence, the present investigation is undertaken.

**2. Materials and Methods**

**2.1 Site description**

A field experiment was conducted at Agricultural and Horticultural Research Station, Bavikere, KSNUAHS, Shivamogga during late *Kharif* 2022 situated at longitude latitude of 75°51`E, 13°42`N & 695 m above the mean sea level. The investigation site had red sandy loam in texture, slightly acidic and non-saline (pH 5.75, EC: 0.24 dSm-1), medium in organic carbon (0.56 %) (Walkley and Black, 1934) [23], low in available nitrogen (224.63 kg ha-1) (Subbiah and Asija, 1956) [21], medium in available phosphorus (52.71 kg ha-1) and medium in available potassium (294.65 kg K2O ha-1) (Jackson, 1973) [7].

**2.2 Experimental details**

The field experiment was conducted in (RCBD) Randomized Completely Block Design involving 11 treatments and 3 replications with plot size 4.5 m x 4.0 m respectively. The treatments comprised of absolute control (T1), recommended dose of fertilizer (100:50:50 kg N:P2O5:K2O ha-1) (T2), 50 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T3), 75 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T4), 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5), 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6), 50 per cent RDN + two sprays of 2 per cent urea fertilizer at 30 & 45 DAT (T7), 75 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T8), 75 per cent RDN + two sprays of 2 per cent urea fertilizer at 30 & 45 DAT (T9), 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10), four sprays of 0.4 per cent nano urea fertilizer at 15, 30, 45 & 60 DAT (T11). Seeds of ragi (cv. GPU-28) were sown in rows of 10 cm apart in the raised beds. At the time of sowing 500 g MOP, 1 kg SSP and 500 g ammonium sulphate per bed were applied to the raised beds, then 12 days after sowing 250 g urea per bed was applied as top dress. Healthy and uniform seedlings of 25 days old were transplanted manually in the main field at 30 cm × 10 cm spacing. On the day of transplanting basal application of 50 per cent of the recommended dose of nitrogen and entire doses of P and K (50: 50 kg ha-1 of P2O5, K2O) were calculated for the experimental plots and applied commonly to all the plots except T1 (control) using urea, single super phosphate and muriate of potash as source. The remaining 50 per cent of the recommended dose of nitrogen was applied at 30 days after transplanting. Nitrogen in the form of nano urea was sprayed at different days after transplanting as per the treatment requirements.

**2.3 Collection of experimental data**

For recording various biometric observations *i.e.,* number of leaves per hill, leaf area index, total dry matter accumulation, absolute growth rate, crop growth rate, grain yield (kg ha-1), straw yield (kg ha-1) and harvest index (%), a sample consisting of five plants was selected at random and tagged in net plot of each treatment. Observations on growth parameters were recorded at 60 and 90 DAT. Five plants were selected at random from the gross plot area through destructive sampling at 60, 90 DAT and at harvest for recording dry matter accumulation (g hill-1).

**2.3.1 Leaf area index (LAI)**

The leaf area index was worked out by using the following formula (Watson, 1952) [24]. Leaf area hill-1 (cm2)

 LAI =

 Ground area (cm2)

**2.3.2 Absolute growth rate (AGR)**

It represents the rate of crop growth and is expressed as g day-1

$$AGR=\frac{W\_{2}-W\_{1}}{t\_{2}-t\_{1}}$$

 Where, W1 and W2 are dry weights of plants at times t1 and t2, respectively.

**2.3.3 Crop growth rate (CGR)**

 Crop growth rate is defined as the rate of dry matter production per unit area per unit time (Watson, 1952) [24]. It can be expressed in g m-2 day-1 and calculated using the formula.

$$CGR=\frac{1}{P}\frac{W\_{2 }- W\_{1 }}{t\_{2 }- t\_{1 }}$$

Where,

 W1 and W2 are dry weights of plants (g m-2) at time t1 and t2, respectively

 P= Ground area covered by the plant

 t2 - t1= Time interval between two stages (days)

 **2.3.4 Nitrogen uptake**

 Nitrogen concentration (%) × Yield of grain / straw (kg ha-1)

 Nitrogen uptake (kg ha-1) =

 100

 **2.3.5 Nitrogen use efficiency**

NUE (%) =

Total nutrient uptake in treated plots

Total nutrient uptake in control plots

-

Nutrient applied (kg ha-1)

×100

**2.4 Statistical analysis**

Experimental data obtained on various parameters were subjected to statistical analysis by adopting Fisher’s method of analysis of variance (ANOVA) as given by Gomez and Gomez (1984) [5]. The results have been discussed at the probability level of five per cent. The level of significance used in “F” test was p = 0.05. Critical difference values were calculated wherever the “F” test was found significant. Otherwise, against CD values abbreviation NS (Non-significant) was indicated.

**3. Results and Discussion**

**3.1 Growth attributes**

The data related to number of leaves per hill and leaf area indexat different growth stages of ragi as influenced by the foliar application of nano and conventional urea are furnished in Table 1.

**3.1.1 Number of leaves per hill**

Application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6) recorded a higher number of leaves per hill (64.26 and 58.42) at 60 and 90 DAT, which was statistically on par with 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10 -61.89 and 56.23) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5-60.78 and 55.28). This may be because conventional urea provided more nitrogen at the early stages of the crop, favoring more leaf production with optimal leaf area under various treatments. Nitrogen is a nutrient element that aids in cell division and cell enlargement. Additional foliar application of nano urea during active tillering stages increased leaf factors, because the readily available nutritional form facilitated greater absorption efficiency, quicker nutrient translocation and increased chlorophyll synthesis and photosynthetic rate (Midde *et al*., 2022) [15]. The absolute control treatment noticed a lower number of leaves per hill (T1-35.24 and 32.15 cm) at 60 and 90 DAT, respectively.

**3.1.2 Leaf area index (LAI)**

Significantly, maximum leaf area index was recorded in 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6- 5.88 and 5.15 at 60 and 90 DAT), which was statistically on par with the application of 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-5.66 and 4.96) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5-5.56 and 4.88). It was caused due to nano urea increasing the chlorophyll formation, rate of photosynthesis results in overall growth in the plant, which may result in the formation of a greater number of leaves. Nitrogen application increased production of the amino acid *i.e.,* tryptophan, which increases the cell elongation thereby contributing to the higher leaf area index (Yadegari, 2013) [25]. In contrast, minimum leaf area index was observed in absolute control (T1-2.26 and 1.98).

**Table 1: Number of leaves per hilland leaf area index of ragi as influenced by the foliar application of nano and conventional urea at different growth stages**

|  |  |  |
| --- | --- | --- |
| **Treatment details** | **Number of leaves hill-1** | **Leaf area index** |
| **60 DAT** | **90 DAT** | **60 DAT** | **90 DAT** |
| T1 - Absolute control | 44.52 | 53.62 | 4.75 | 4.78 |
| T2 - Recommended dose of fertilizer (100:50:50 kg N:P2O5:K2O ha-1) | 70.15 | 86.25 | 8.02 | 8.09 |
| T3 - 50 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 61.58 | 75.08 | 6.93 | 6.98 |
| T4 - 75 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 66.24 | 81.59 | 7.58 | 7.65 |
| T5 - 75 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 71.95 | 89.46 | 8.34 | 8.42 |
| T6 - 100 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 75.82 | 94.13 | 8.76 | 8.85 |
| T7 - 50 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 58.27 | 71.09 | 6.57 | 6.59 |
| T8 - 75 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 60.56 | 73.98 | 6.82 | 6.87 |
| T9 - 75 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 67.34 | 82.97 | 7.69 | 7.78 |
| T10- 100 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 73.12 | 90.86 | 8.46 | 8.54 |
| T11 - Four sprays of 0.4 % nano urea fertilizer at 15, 30, 45 & 60 DAT | 51.38 | 62.54 | 5.78 | 5.83 |
| **S. Em (±)** |  **2.02** | **2.65** | **0.24** |  **0.25** |
| **CD (*p*=0.05)** |  **5.95** |  **7.82** |  **0.72** |  **0.73** |

**3.1.3 Total dry matter accumulation (g hill-1)**

The treatment supplied with the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6) recorded a maximum total dry matter (25.37, 44.62 and 46.75 g hill-1) at 60, 90 DAT and at harvest (Table 2), which was on par with 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-24.46, 43.09 and 45.16 g hill-1) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5-24.05, 42.49 and 44.52 g hill-1). It’s because of the site-specific absorption of nano nitrogen, which was utilized according to the needs of the plant that led to good vegetative growth. Ultimately, increasing metabolic and meristematic activity, cell division, cell elongation and improvement in growth parameters like plant height, number of leaves and leaf area resulted in increased total dry matter accumulation (Rani *et al.,* 2019) [17]. The use of nanoparticles accelerates photosynthesis, improving the transfer of assimilates and photosynthates to various plant sections and increasing the accumulation of dry matter in the plant (Singh and Kumar, 2017) [20]. Significantly, lower total dry matter was observed in absolute control (T1-13.42, 23.65 and 24.95 g hill-1).

**3.1.4 Absolute growth rate (g day-1)**

Over the stages of the crop, highest absolute growth rate (0.64 g day-1) was observed during 60-90 DAT with the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6). However, lowest absolute growth rate (0.34 g day-1) was recorded in absolute control (T1) treatment (Table 2). The increase in dry matter accumulation with foliar application of nano nitrogen nutrient resulted in the ready availability of nutrients at critical period of crop demand. These results are in findings with Alimamy *et al*., (2022) [1].

**3.1.5 Crop growth rate (g m-2 day-1)**

Maximum crop growth rate (21.39 g m-2 day-1) was recorded during 60-90 DAT (Table 2) in the treatment supplied with the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6). It is due to the fact that nano nutrients supplied through foliage has mobilised more efficiently by the plant resulting in enhanced growth attributes and ultimately enhanced the crop growth rate and relative growth rate and net assimilation rate. The above results are also in conformity with the findings of Kaviyazhagan *et al*., (2022) [9]. In contrast, absolute control (T1) treatment recorded minimum crop growth rate (11.39 g m-2 day-1).

**3.2 Yield**

The data on yield components *viz.,* grain yield, straw yield and harvest index were recorded at harvest as influenced by the foliar application of nano urea and conventional urea are presented in Table 3.

**3.2.1 Grain yield (kg ha-1)**

Maximum grain yield (3812 kg ha-1) was recorded with the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6), which was statistically close with the application of 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-3664 kg ha-1) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5-3589 kg ha-1). The improved root establishment and increased foliar growth during the vegetative stage of the crop brought by the basal application of conventional urea. This early, optimum growth facilitates the efficient absorption of nano urea at later development stages and enhances the physiological and metabolic processes in the plant systems promoting the transport of photosynthates from source to sink (Kumar *et al*., 2020) [12]. However, lower grain yield (1428 kg ha-1) was recorded in absolute control (T1).

 **Table 2: Total dry matter accumulation, absolute growth rate (AGR) and crop growth rate (CGR) of ragi as influenced by the foliar application of nano and conventional urea at different growth stages**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment details** | **Total dry matter accumulation (g hill-1)** | **AGR (g day-1)** | **CGR (g m-2 day-1)** |
| **60 DAT** | **90 DAT** | **At harvest** | **30 - 60 DAT** | **60 - 90 DAT** | **30 - 60 DAT** | **60 - 90 DAT** |
| T1 - Absolute control | 13.42 | 23.65 | 24.95 | 0.33 | 0.34 | 10.86 | 11.37 |
| T2 - Recommended dose of fertilizer (100:50:50 kg N:P2O5:K2O ha-1) | 23.19 | 40.86 | 42.83 | 0.56 | 0.59 | 18.63 | 19.63 |
| T3 - 50 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 20.18 | 35.58 | 37.36 | 0.51 | 0.51 | 16.89 | 17.11 |
| T4 - 75 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 21.86 | 38.67 | 40.58 | 0.54 | 0.56 | 17.96 | 18.68 |
| T5 - 75 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 24.05 | 42.49 | 44.52 | 0.61 | 0.61 | 20.44 | 20.49 |
| T6 - 100 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 25.37 | 44.62 | 46.75 | 0.63 | 0.64 | 21.11 | 21.39 |
| T7 - 50 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 19.12 | 33.71 | 35.41 | 0.47 | 0.49 | 15.74 | 16.22 |
| T8 - 75 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 19.85 | 35.08 | 36.82 | 0.47 | 0.51 | 15.81 | 16.92 |
| T9 - 75 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 22.31 | 39.34 | 41.27 | 0.55 | 0.57 | 18.41 | 18.92 |
| T10- 100 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 24.46 | 43.09 | 45.16 | 0.60 | 0.62 | 20.16 | 20.70 |
| T11 - Four sprays of 0.4 % nano urea fertilizer at 15, 30, 45 & 60 DAT | 16.53 | 29.83 | 31.28 | 0.41 | 0.44 | 13.66 | 14.78 |
| **S. Em (±)** | **0.71** | **1.26** |  **1.30** | **0.02** | **0.02** | **0.55** | **0.52** |
| **CD (*p*=0.05)** |  **2.10** |  **3.72** |  **3.84** |  **0.04** |  **0.05** |  **1.62** |  **1.53** |

**Table 3: Grain yield, straw yield and harvest index of ragi as influenced by the foliar application of nano and conventional urea**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment details** | **Grain yield** **(kg ha-1)** | **Straw yield** **(kg ha-1)** | **Harvest index (%)** |
| T1 - Absolute control | 1428 | 2741 | 34.25 |
| T2 - Recommended dose of fertilizer (100:50:50 kg N:P2O5:K2O ha-1) | 3487 | 5926 | 37.04 |
| T3 - 50 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 3023 | 5268 | 36.46 |
| T4 - 75 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 3268 | 5624 | 36.75 |
| T5 - 75 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 3589 | 6105 | 37.02 |
| T6 - 100 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 3812 | 6453 | 37.13 |
| T7 - 50 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 2846 | 5012 | 36.22 |
| T8 - 75 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 2961 | 5157 | 36.47 |
| T9 - 75 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 3345 | 5749 | 36.78 |
| T10- 100 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 3664 | 6235 | 37.01 |
| T11 - Four sprays of 0.4 % nano urea fertilizer at 15, 30, 45 & 60 DAT | 2439 | 4386 | 35.73 |
| **S. Em (±)** | **107.41** | **161.63** | **1.12** |
| **CD (*p*=0.05)** | **316.86** | **476.82** | **NS** |

**3.2.2 Straw yield (kg ha-1)**

Application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6) has recorded higher straw yield (6453 kg ha-1), which was found statistically on par with the application of 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-6235 kg ha-1) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5-6105 kg ha-1). The increase in the straw yield with the foliar spray of nano urea might be due to their rapid uptake by the plants and translocation at a faster pace, which aided in a higher rate of photosynthesis and more dry matter accumulation which resulted in higher straw yield. These findings were in agreement with the reports of Khalil *et al.* (2019) [11] in maize and Sahu *et al.* (2022) [18] in rice. In contrast, absolute control (T1) recorded lower straw yield (T1-2741 kg ha-1).

**3.2.3 Harvest index (%)**

There was no significance difference among different treatments w.r.t to harvest index of ragi as influenced by foliar application of nano and conventional urea. However, numerically highest harvest index (37.13 %) was recorded with the application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6). However, absolute control treatment (T1) recorded lower harvest index (34.25 %).

**3.3 Nitrogen uptake (kg ha-1)**

The data narrating nitrogen uptake at harvest in ragi as influenced by foliar application of nano and conventional urea is furnished in Table 4.

Compared to other treatments, 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6) has recorded significantly higher total nitrogen uptake (89.60 kg ha-1) at harvest which was statistically close with the 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-85.16 kg ha-1) and 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5- 80.24 kg ha-1). The nitrogen uptake was found to be increased with the foliar application of nano urea, which might be due to nano fertilizer have large surface area and particle size is less than the pore size of root and leaves of the plant which can increase their penetration into the plant from applied surface and improve nutrient uptake. These results findings were in close agreement with the findings of Lahari *et al*. (2021) [13]. On the other hand, the absolute control (T1) recorded a lower total nitrogen uptake (19.69 kg ha-1) at harvest.

**3.4 Nitrogen use efficiency (%)**

The data pertaining to nutrient use efficiency in ragi as influenced by the foliar application of nano and conventional urea is furnished in Table 4.

Significantly higher nitrogen use efficiency (48.41 %) was observed with the application of 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT (T5), which was statistically on par with the 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT (T6-46.59 %) and 100 per cent RDN + one spray of 2 per cent urea fertilizer at 30 DAT (T10-43.65 %). This increase in nitrogen use efficiency was mainly due to the properties of nano urea *i.e.,* large surface area and particle size smaller than the pore size of plant leaves, allowing for greater penetration into plant tissues from the applied surface and improved absorption and nutrient use efficiency. Nanoparticles with a size of less than 5 nm go through the cuticular pathway, whereas those with larger sizes travel through the stomatal pathway before arriving at the conducting system, where they aid in the rapid and simple absorption of nutrients by leaves. (Dimkpa *et al.,* 2015 and Qureshi *et al.,* 2018) [4, 16]. However, plots received with the recommended dose of fertilizer (T2) recorded lower nitrogen use efficiency (36.41 %) compared to the above treatments.

**Table 4: Nitrogen uptake and use efficiency at harvest as influenced by the foliar application of nano and conventional urea in ragi**

|  |  |  |
| --- | --- | --- |
| **Treatment details** | **Nitrogen uptake (kg ha-1)** | **Nitrogen use efficiency (%)** |
|  | **Grain** | **Straw** | **Total** | **N** |
| T1 - Absolute control | 11.74 | 7.95 | 19.69 | - |
| T2 - Recommended dose of fertilizer (100:50:50 kg N:P2O5:K2O ha-1) | 45.45 | 28.85 | 74.30 | 36.41 |
| T3 - 50 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 35.07 | 23.01 | 58.08 | 38.36 |
| T4 - 75 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 41.37 | 25.73 | 67.10 | 37.92 |
| T5 - 75 % RDN + Two sprays of 0.4 % nano urea fertilizer at 30 & 45 DAT | 48.99 | 31.25 | 80.24 | 48.41 |
| T6 - 100 % RDN + One spray of 0.4 % nano urea fertilizer at 30 DAT | 54.67 | 34.93 | 89.60 | 46.59 |
| T7 - 50 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 31.41 | 19.74 | 51.15 | 29.75 |
| T8 - 75 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 33.56 | 21.01 | 54.57 | 27.28 |
| T9 - 75 % RDN + Two sprays of 2 % urea fertilizer at 30 & 45 DAT | 43.31 | 26.86 | 70.17 | 38.61 |
| T10- 100 % RDN + One spray of 2 % urea fertilizer at 30 DAT | 52.29 | 32.87 | 85.16 | 43.65 |
| T11 - Four sprays of 0.4 % nano urea fertilizer at 15, 30, 45 & 60 DAT | 22.58 | 14.67 | 37.25 | 34.98 |
| **S. Em (±)** | **2.59** | **1.62** | **4.20** | **1.97** |
| **CD (*p*=0.05)** | **7.67** | **4.79** | **12.40** | **5.81** |

**4. Conclusion**

From the above study, it is concluded that application of 100 per cent RDN + one spray of 0.4 per cent nano urea fertilizer at 30 DAT recorded higher growth and yield parameters *i.e.,* number of leaves per hill, leaf area index, total dry matter accumulation, absolute growth rate, crop growth rate, grain yield and straw yield of ragi as compared to recommended dose of fertilizer. The combined application of 75 per cent RDN + two sprays of 0.4 per cent nano urea fertilizer at 30 & 45 DAT revealed higher total nitrogen uptake and use efficiency (89.60 kg ha-1 and 48.41 %) as compared to recommended dose of fertilizer (74.30 kg ha-1 and 36.41 %).

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