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Research Article

Effect of Nano Fertilization on Growth Analysis and Fodder Yield of Multicut Sorghum (*Sorghum bicolor* L. Var. Pant Chari-6)

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Abstract

A field experiment was conducted during Kharif 2023 at Forage Agronomy Block, Instructional Dairy Farm, Nagla of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India with the objectives to investigate the effect of nano fertilization on growth analysis and fodder yield of multicut sorghum (Sorghum bicolor L. var. Pant Chari-6)'. The experiment was consisted of 13 treatments i.e T_1: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1stcut, T_3: 60 kg Nha^{-1}(basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1}(basal) fb NU and NZn 1st cut, T5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut, T6: 45 kg Nha-1(basal) fb NU 1st cut, T_7: 45 kg Nha-1(basal) fb NU 1st and 2nd cut, T8: 45 kg Nha^{-1} (basal) fb NU and NZn 1stcut, T_9: 45 kg Nha^{-1} (basal) fb NU and NZn at 1st and 2nd cut, T_{10}: NU 25 DAS fb NU 1st and 2nd cut, T_{11}: NU basal (furrows) fb NU 1st and 2nd cut, T_{12}: Band placement 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut replicated thrice in randomized block design. The results revealed that the plant height, number of tillers, leaf area index, growth analysis i.e. CGR, RGR and NAR and fodder yield were recorded statistically higher at application of60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut. This treatment produced significantly higher green and dry fodder yields that were statistically equal to T_1: 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st cut and 2nd cut, , T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut and T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut and T_{13}: band placement 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st and 2nd cut with 1.4, 4.3, 5.0 and 1.3% higher green fodder yield and 2.8, 5.8, 6.2 and 1.4% dry fodder yield, respectively. It indicates that two spray of nano urea and nano zinc can save 60 kg nitrogen ha^{-1} . Therefore it is recommended that application of 60 kg Nha^{-1} (basal) followed by spray of nano urea and nano zinc at 1st and 2nd cut may not only increase fodder yield but also save 60 kg chemical nitrogen ha^{-1}.

Keywords: (CGR); (RGR); (NAR); Nano Fertilization; Nano Zinc

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is the most popular fodder crops grown in Kharif and summer seasons and it is also known as jowar, cholam and jonna in different parts of India. It is well adapted to drought and moisture limiting conditions due to its higher water use efficiency and so referred as "Camel crop". It suits to deep, well-drained and loamy clay soil with a pH range of 5.5 to 7.5. Sorghum provides nutritious fodder and fed in different forms like green chop, hay and silage to the livestock. Multi-cut fodder sorghum is now preferred over single cut due to its higher productivity [8]. Sorghum accounts 41.64 Mha area with production of 62.17 mt worldwide. In India, it is cultivated in 2.6mha area with fodder productivity of 35-70 tons ha^{-1}. At present, our country has a net deficit of 35.60% green fodder, 10.95% dry fodder and 44% concentrate feed ingredients [9]. Total forage production is 833 mt including 390 mt green and 443 mt dry fodder, whereas the annual forage requirement is 1594 mt (1025 mt green and 569 mt dry). With the increasing livestock population, the forage requirement will be 1012 mt of green and 631 mt dry fodder in 2050. With the current rate of fodder supply, there will be 18.4% deficit in green and 13.2% in dry fodder by the year 2050. So, it is necessary to fulfil the gap by improving annually green forage production by 1.69%. One of the major constraints in sorghum fodder production is fertilizer management, hence precise dose and time of fertilizer application need to relook to enhance the fodder production and its availability to livestock. Nitrogen is one of the major deficient nutrients due to its highly soluble nature and leaches down in most of the soils. The use of nano fertilizer in place of conventional fertilizer is one of the option because of its low amount, slow release, higher surface area and pollution free [15].

Nano-materials having a size between 1 and 100 nm improve plant's performance in terms of higher uptake, photosynthesis, leaf area and crop yield [14]. Nano urea and nano zinc are generally applied through foliar spray [10,11]. Due to their small size, nano particles can easily diffuse and absorb in leaves through stomata or leaf epidermis and enter into plants through apoplast and symplast pathways and translocate through xylem and phloem and also transported to different plant parts [16]. Therefore the present study was made to study the effect of combined chemical and nano fertilization on growth analysis and fodder yield of sorghum in Indo-Gangetic plains of India.

Materials and Methods

The experiment was carried out at Forage Agronomy Block, Instructional Dairy Farm, Nagla, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India in *Kharif*-2023. The experimental site is situated in *Tarai* region of Uttarakhand state at latitude of 29°N, longitude of 79.3°E and an altitude of 243.84m above the mean sea level. The experimental site was neutral in soil reaction, medium in organic carbon (0.75%), low in available nitrogen (198.43 kg ha^{-1}), whereas available phosphorus (21.34 kg ha^{-1}), available potassium (235.43 kg ha^{-1}), available zinc (1.15 ppm) and organic carbon organic carbon (0.75%) were in the medium range. The experiment was consisted of 13 treatments and replicated thrice in randomized block design (Table 1). The recommended dose for multicut fodder sorghum is N: P_2O_5: K_2O: 120:60:40 kg ha^{-1}. The fertilizer sources were, urea and nano urea, single super phosphate (SSP) and muriate of potash (MOP) and nano zinc, as per the treatments. Full dose of phosphorus and potassium and half dose of nitrogen was applied as basal in all the treatments at the time of sowing. The nitrogen in form of urea was applied as per the treatment requirement besides, nano urea 4 ml L^{-1} and nano zinc 2 ml L^{-1} were applied as foliar spray to replace the top dressing of urea at different cuts as per treatments. In T_{11} nano urea was sprayed in furrows at the time of sowing. Similarly in treatment T_{12} and T_{13} nitrogen was placed in bands after opening the furrows 5 cm away from seed. The multicut sorghum variety Pant Chari-6 was sown in crop geometry of 30 cm × 5 cm at 5cm sowing depth taking seed rate 20 kg ha^{-1}. It was harvested 3 times and each cutting was done at a height of 8-10 cm above ground level for better regeneration. The first cutting was done at 45 DAS followed by 2nd cut at 75 DAS and 3rd cut at 105 DAS. Therefore, observations were recorded after each cuts. Growth analysis was made with standard techniques with dry matter accumulation. The green and dry fodder yield were recorded from net area of each treatment and expressed in tons/ha.

Result and Discussion

Growth and growth analysis

The plant height differed significantly among different treatments and it decreased with subsequent cuts (Table 2). The tallest plants were measured under T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at first and second harvest, whereas T_1: 60kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_3: 60 kg Nha-1 (basal) fb NU 1st and 2nd cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st and 2ns cut at third harvest.. The average tallest plant was recorded significantly at T_5: 60 kg Nha-1 (basal) fb NU and NZn 1st and 2nd cut that was significantly equal to T_1: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_{12}: Band placement 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut with 3.l, 7.0, 7.4 and 1.8% higher values respectively. The average plant height was recorded significantly lower at T_{11}: NU basal (furrows) fb NU 1st and 2nd cut that was statistically at par with T_{10}: NU 25 DAS fb NU 1st and 2nd cut. The taller plants were attributed to higher fertilization i.e. application of RDN along with nano urea and nano zinc because nitrogen plays major role in plant cell protoplasm, cell division and photosynthetic efficiency where-

Symbol	Treatment	Abbreviated form
T1	RDF: 60 kg Nha^{-1} as basal + Top dressing of 30 kg Nha^{-1} after each 1st cut (45DAS) and 2nd cut (75DAS)	T1: 60 kg Nha^{-1} (basal) *fb* 30 kg Nha^{-1} 1st and 2nd cut
T2	60 kg Nha^{-1} as basal + Nano Urea (0.4%) spray after 1st cut	T2: 60 kg Nha-1 (basal) *fb* NU 1stcut
T3	60 kg Nha^{-1} as basal + Nano Urea (0.4%) spray after each 1st and 2nd cut	T3: 60 kg Nha^{-1} (basal) *fb* NU 1st and 2nd cut
T4	60 kg Nha-1as basal + Nano Urea (0.4%) and Nano Zinc (0.2%) spray after 1st cut	T4: 60 kg Nha^{-1} (basal) *fb* NU and NZn 1st cut
T_5	60 kg Nha^{-1} as basal + Nano Urea (0.4%) and Nano Zinc spray (0.2%) after each 1st and 2nd cut	T5: 60 kg Nha^{-1} (basal) *fb* NU and NZn 1st and 2nd cut
T_6	45 kg Nha^{-1} as basal + Nano urea (0.4%) spray after 1st cut	T6: 45 Nha^{-1} (basal) *fb* NU 1st cut
T_7	45 kg Nha^{-1} as basal + Nano urea (0.4%) spray after each 1st and 2nd cut	T7: 45 kg Nha^{-1} (basal) *fb* NU 1st and 2nd cut
T_8	45 kg Nha^{-1} as basal + Nano urea (0.4%) and Nano zinc (0.2%) spray after 1st cut	T8: 45 kg Nha^{-1} (basal) *fb* NU and NZn 1st cut
T_9	45 kg Nha^{-1} as basal + Nano urea (0.4%) and Nano zinc (0.2%) spray after each 1st and 2nd cut	T9: 45 kg Nha^{-1} (basal) *fb* NU and NZn at 1st and 2nd cut
T_{10}	Nano urea (0.4%) spray at vegetative stage (25 DAS) and after 1st and 2nd cut	T10: NU 25 DAS *fb* NU 1st and 2nd cut
T_{11}	Basal application of Nano Urea (0.4%) in furrows followed by Nano Urea (0.4%) spray at 1st and 2nd cut	T11: NU basal (furrows) *fb* NU 1st and 2nd cut
T_{12}	Band placement of 60 kg Nha^{-1} as basal + 30 kg N ha-1 after 1st cut	T_{12}: Band placement 60 kg Nha^{-1} (basal) *fb* 30 kg Nha^{-1} 1st cut
T_{13}	Band placement of 60 kg Nha^{-1} as basal + 30 kg N ha-1 after 1st and 2nd cut	T_{13}: Band placement 60 kg Nha^{-1} (basal) *fb* 30 kg Nha-1 1st and 2nd cut

Table 1: Detail of treatments.

as, zinc is responsible for catalyzing enzyme activity, increases protein synthesis and plays vital role in improving nitrogen uptake in plants [3,17].

Number of tillers per square meter was decreased with subsequent cuttings and affected significantly with nano fertilization (Table 2). The highest tillers was counted at T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at first harvest, T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at second harvest and T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at third harvest. The average values were recorded significantly higher at T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was non-significant with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut. The average number of tillers per meter row length was recorded significantly lower in T_{11}: NU basal (furrows) fb NU 1st and 2nd cut that was statistically equal to T_{10}: NU 25 DAS fb NU 1st and 2nd cut. Twice spray of nano-urea along with RDN increased the nutrient uptake through stomatal apertures and nutrient translocation in the plant leading to enhanced nutrient uptake, cell division, meristmatic activity and cell elongation resulted in more productive tillers per plants and similar results were also reported [12].

Nano fertilization had significant influence on LAI that had declining trend with subsequent cuttings (Table 2). The highest LAI was recorded under T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at first harvest which remained at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st cut and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut and T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut. Similarly, T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut had the highest LAI that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at second harvest and T_1: 60 kg Nha-1 (basal) fb 30 kg Nha^{-1} 1st and 2nd cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at third harvest. However an average LAI was found significantly higher at T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut and T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut. The lowest average LAI was observed in treatments T_{10}: NU 25 DAS fb NU 1st and 2nd cut and T_{11}: NU basal (furrows) fb NU 1st and 2nd cut. The higher leaf area index was the result of higher availability of nitrogen and chlorophyll content that improved leaf growth and leaf elongation. Similar results were also reported [6].

Nano fertilization had significant effect on growth analysis i.e. (CGR), (RGR) and (NAR) (Table 3). The highest (CGR), (RGR) and (NAR) were noted under T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was non-significant with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at both first and second harvest , whereas T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at third harvest. The highest average CGR was recorded under T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1stst and 2nd cut that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut and T_{13}: Band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut. The lowest average values of (CGR), (RGR) and (NAR) were filed under T_{11}: NU basal (furrows) fb NU 1st and 2nd cut. The higher values of growth analysis were the result of taller plants, more number of tillers and dry matter accumulation at higher dose of fertilization and similar results were also reported [4,5].

Fodder yield

The data reveals that green fodder yields of multicut fodder sorghum was influenced by the nano fertilization (Table 4). The highest green fodder yield was noted under T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was statistically at par with T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha-1 1st and 2nd cut, T_2: 60 kg Nha^{-1} (basal) fb NU 1st cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and T_{13}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at first harvest , T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut, T_{12}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha-1 1st cut and T_{13}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at second harvest and T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut and T_{13}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut at third harvest. The total green fodder yield was recorded higher at T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was statistically equal to T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st cut and 2nd cut, , T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut and T_4: 60 kg Nha^{-1}(basal) fb NU and NZn 1st cut and $T_1$3: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut with 1.4, 4.3, 5.0 and 1.3% higher values, respectively.

The total green fodder was recorded significantly lowest under treatment T_{11}: NU basal (furrows) fb NU 1st and 2nd cut. In general, treatments, T_6 to T_9 where basal application of 45 kg Nha^{-1} was applied along with different combination of nano urea and zinc produced lower green fodder yield mainly because of lower values of growth attributes. The higher green fodder yield was attributed to better growth attributes like plant height, number of tillers, LAI, growth rates and net assimilation rate. Precise foliar spray of the nano fertilizers increases the uptake and also reduces the leaching losses [2]. It was also observed that band placement of nitrogen under treatment of T_{13}: band placement 60 kg Nha^{-1} (basal) fb 30 kg

Nha^{-1} 1st and 2nd cut was found equally good as compare to the best treatment T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut being non-significant to each other. Sandral., *et al*. [13] also reported higher yield of wheat under band placement.

The dry fodder yield had a similar patter as green fodder yield, however the total dry fodder yield was also recorded significantly higher at T_5: 60 kg Nha^{-1} (basal) fb NU and NZn 1st and 2nd cut that was statistically equal to T_1: 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut, T_3: 60 kg Nha^{-1} (basal) fb NU 1st and 2nd cut, T_4: 60 kg Nha^{-1} (basal) fb NU and NZn 1st cut and T_{13}: band placement 60 kg Nha^{-1} (basal) fb 30 kg Nha^{-1} 1st and 2nd cut with 2.8, 5.8, 6.2 and 1.4% higher values, respectively. Application of recommended dose of fertilizers along with nano urea and nano zinc had a better growth with higher chlorophyll content leading to high photosynthesis and high green and dry fodder yield [1,7].

Conclusion

Based on above findings, it is concluded that application of 60 kg Nha^{-1} (basal) followed by spray of nano urea and nano zinc at 1st and 2nd cut may not only increase growth and fodder yield but also save 60 kg chemical nitrogen ha^{-1}.

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