Biological Forum – An International Journal 15(10): 1470-1477(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Response of Finger Millet to Nano Nitrogen and Nano Zinc for Enhancing Productivity

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(Received: 19 August 2023; Revised: 25 September 2023; Accepted: 08 October 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: Plant nutrition is critical for increased development and productivity. Nitrogen and zinc are the most limiting macro and micro nutrient that determines the crop productivity. Foliar application of these nutrients is a well-known strategy to abate acute deficiency at any crop growing stage. Recent developments in the field of nano-technology such as spraying of nano-urea and nano-zinc in combination with conventional fertilizers enhances crop growth and productivity. A field experiment was conducted at Dryland Agriculture project, UAS, GKVK, Bengaluru during *Kharif* 2021 and 2022 to study the effect of nano-N and nano-Zn on growth and productivity of finger millet. The experiment was laid out in RCBD with factorial concept and replicated thrice. The experiment consists of 18 treatments with four levels of nitrogen (A_1: No nitrogen, A_2: 50% RDN, A_3: 75% RDN and A_4: 100% RDN) and four methods of fertilizer application (B_1: Soil application of zinc, B_2: Foliar application of nano nitrogen @ 35 and 55 DAS, B_3: Foliar application of nano zinc @ 35 and 55 DAS and B_4: Foliar application of nano nitrogen and nano zinc @ 35 and 55 DAS) along with two control. For all the treatments, phosphorus and potassium were applied as per standard recommendations. The results revealed that application of 100 per cent RDN along with spraying of nano-N and nano-Zn twice at 35 and 55 DAS recorded significantly higher growth parameters *viz.*, plant height, total dry matter production, leaf area index and crop growth rate at all the growth stages. Similarly, significantly higher grain yield (3453 kg ha^{-1}) and straw yield (5048 kg ha^{-1}) was recorded with application of 100 per cent RDN along with spraying of nano-N and nano-Zn and was on par with the application of 75 percent RDN with spraying of nano-N and nano Zn twice (3449 kg ha^{-1} and 5035 kg ha^{-1}, respectively). Thus, application of 75% RDN with spraying of nano-N and nano-Zn was found to be useful in enhancing the productivity of finger millet.

Keywords: Finger millet, Nano nitrogen, Nano zinc, RDN.

INTRODUCTION

Recently, small millets are promoted as 'nutri-cereals' and climate smart crops because of their ability to withstand unfavorable consequences of climate change facilitating food and nutritional security for burgeoning population, especially in resource-poor and rainfed areas (Kumar *et al*., 2019). Among various small millets, finger millet (*Eleusine coracana* L. Gaertn), commonly known as 'ragi' is the most important crop in terms of its higher production and wider adaptability. It is one of the important small millets having potential to produce considerable quantity of nutritious food grains (Banerjee and Maitra 2020) under suboptimal resource and management conditions. In India, 1.70 million tones of finger millet is produced from a total area of 1.21 million hectares with an average productivity of 1396 kg ha^{-1} (Anon., 2022). Among Indian states, Karnataka, Tamil Nadu, Andhra Pradesh, Odisha, Jharkhand, Uttaranchal, Maharashtra and Gujarat are confined for finger millet cultivation (Ramya *et al*., 2020). In Karnataka, it occupied an area of 0.85 million hectares with a production of 1.13 million tonnes with an average productivity of 1332 kg ha^{-1} (Anon., 2022) indicating the lion share in finger millet production.

Recently developed varieties of finger millet are highly responsive to nutrients (Panda *et al*., 2021). To achieve higher productivity, adequate supply of nutrients through the right source could be an important approach. Nutrients are vital for maintaining and improving crop growth and yield. The efficiency of fertilizer use decreases with increased amount of fertilizer applied. When nutrient application is not synchronized with crop demand, losses from the soil-plant system are large leading to lower fertilizer use efficiency. Therefore, there is a need for the development of suitable nutrient recommendation technique to improve fertilizer use efficiency.

To address these problems, there is a need to explore one of the frontier technologies such as 'Nanotechnology. Nanotechnology is the art and science of manipulating matter at nanoscale. Because nano particles are spherical or faceted metal particles typically < 100 ηm in size. These nano particles are having higher surface area (30-50 m^2 g^{-1}), higher activity, rapid chemical reaction, rapidly dispersible and adsorb abundant water. Nano-fertilizers are new generation synthetic fertilizers which contain readily available nutrients in nano-scale range. So nano fertilizers may increase the efficiency of nutrient uptake, enhance yield and nutrient content in the edible parts and also minimize its accumulation in the soil.

Among the various nutrients, the physiological role of nitrogen and zinc attributes to enhance crop productivity (Ramya *et al.*, 2020). Apart from soil applications, foliar spray of nutrients has been shown to be a practical means of replenishing the reservoir of nutrients in the leaves. In deed supplementation of nutrients, through foliar spray could be most efficient and appropriate strategy (Liu and Lal 2015). So far, several researchers have found the beneficial effect of nano fertilizers on different crops, but the use of nano fertilizers on finger millet is scarce. Hence, the present investigation was undertaken.

MATERIAL AND METHODS

The field experiment was carried out for two consecutive years in 2021 and 2022 at AICRPDA, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru. The soil of the experimental site was red sandy clay loam in texture. The soil of the experimental site was strongly acidic in reaction (4.68), the soil was low in organic carbon content (0.40 %) and available nitrogen (256.08 kg ha^{-1}), high in available phosphorus (51.31 kg ha^{-1}) and medium in potassium (146.34 kg ha^{-1}).

The experiment consists of 18 treatments with four levels of nitrogen (A_1: No nitrogen, A_2: 50% of RDN, A_3: 75% RDN and A_4: 100% RDN) and four methods of fertilizer application (B_1: Soil application of zinc, B_2: Foliar application of nano nitrogen @ 2ml l^{-1} at 35 and 55 DAS, B_3: Foliar application of nano zinc @ 2ml l^{-1} at 35 and 55 DAS and B_4: Foliar application of nano nitrogen and nano zinc @ 2ml l^{-1} at 35 and 55 DAS) along with two control. For all the treatments, phosphorus and potassium were applied as per standard recommendations. RDF for finger millet is 50:40:37.5:12.5 kg NPKZn ha^{-1}. Growth parameters like plant height, total dry matter production, leaf area index and crop growth rate of five randomly selected plants were recorded at 30, 60, 90 DAS and at harvest. The grain and straw yield obtained from each net plot area was converted to kgha^{-1}.

RESULTS AND DISCUSSION

Growth parameters as influenced by levels of nitrogen and method of fertilizer application in finger millet Plant height. The data pertaining to effect of levels of nitrogen and method of fertilizer application on plant height was recorded at 30, 60, 90 DAS and at harvest are presented in Table 1.

Plant height is an important parameter related to growth and development of crop. At 30 DAS, there was no significant difference in plant height of finger millet. The average plant height was significantly influenced by levels of nitrogen at 60, 90 DAS and at harvest. Increasing application of nitrogen from 50 per cent to 100 per cent showed increased plant height. Significantly higher plant height was observed in 100 per cent RDN at 60 DAS (60.95 cm), 90 DAS (89.69 cm) and at harvest (93.33 cm) and was on par in 75 per cent RDN (59.30, 86.93 and 90.68 cm, respectively). Lower plant height was exhibited without application of nitrogen (43.19, 70.03 and 73.78 cm, respectively). Among the methods of fertilizer application, foliar application of nano-N and nano-Zn at 35 and 55 DAS has recorded taller plants at 60 DAS (56.41 cm), 90 DAS (85.62 cm) and at harvest (89.18 cm) which was followed by the foliar application of only nano-N at 35 and 55 DAS whereas, application of conventional zinc to soil has lower plant height. Among various interactions, significantly higher plant height was observed with combined application of 100 per cent RDN + foliarspray of nano-N andnano-Zn (66.30, 96.28, 100.49 cm) at 60, 90 DAS and at harvest, respectively which was on par with application of 75 per cent N and recommended PK with foliar spray of nano-N and nano-Zn (66.24, 96.13 and 100.42 cm). The lowest plant height was seen with application of only PK (control-1).

Plant height was improved with the higher level of fertilizer application. An adequate supply of nutrients during the initial period helped for better accumulation and translocation of photosynthates which resulted in taller plants with increased N levels. Such a favorable effect of RDN on increase in plant height has been reported earlier by Babu *et al.* (2013). Nitrogen fertilizer leads to the elongation of stem internodes, especially the basal internodes, thus increasing plant height (Chou, 2020). Experimental results concerning crop plant height impacted by method of fertilizer application. The findings revealed that foliar treatment of both nitrogen and zinc in nano form performed better than others in terms of plant height, closely followed by foliar application of nano-N. This was due to the appropriate supply of nitrogen and zinc resulted in accelerated enzyme and auxin metabolism in the plant which enlarged the cell and resulted in cell division and elongation, resulting in taller plants. So, foliar spray of nano-N and nano-Zn reported the higher plant height at 60, 90 and at harvest. Application of nano nitrogen and nano zinc in combination with conventional fertilizers resulted in higher plant height as it increased metabolic process in plant which has promoted meristematic activities causing higher apical growth and photosynthetic area. The results are in line with Mardalipour *et al*. (2014); Manikandan *et al*. (2015).

Total dry matter production (g hill^{-1}). The data on total dry matter production (TDMP) at various growth stages revealed that TDMP was significantly influenced by nitrogen levels and methods of fertilizer application (Table 2). The TDMP per hill increased continuously from emergence to harvest. The greater TDMP per hill was recorded at harvest. The rate of increase of dry matter was faster between 30 to 60 DAS and thereafter the increase was slow up to harvest.

The maximum TDMP at 60 DAS, 90 DAS and at harvest was found with the application of 100 per cent RDN (21.28, 41.09 and 56.51 g hill^{-1}, respectively) and was on par with application of 75 per cent RDN (20.27, 40.30 and 55.05, g hill^{-1}, respectively) which was superior over 50 per cent RDN. Among method of fertilizer application, foliar application of nano-N and nano-Zn has recorded higher TDMP at 60 DAS (20.76 g hill^{-1}), 90 DAS (40.70 g hill^{-1}) and at harvest (53.46 g hill^{-1}) followed by foliar application of only nano-N (19.20, 38.90 and 50.81 g hill^{-1}, respectively). There was significant interaction between nitrogen levels and method of fertilizer application, among different combinations 100 per cent RDN with foliar spray of nano-N and nano-Zn has recorded significantly higher dry matter production per hill at 60 DAS (24.87 g hill^{-1}), 90 DAS (44.88 g hill^{-1}) and at harvest (61.05 g hill^{-1}) which was on par with application of 75 per cent RDN + foliar application of nano-N and nano-Zn (24.23, 44.84 and 61.64 g hill^{-1}, respectively). Significantly lower dry matter production per hill was recorded in with application of only PK (control-1).

Better plant growth led to more dry matter accumulation in leaves and stems at early growth stages and better transfer to grain at later stages, resulting in higher total dry matter production. Similar findings were observed by Miller and Sayre (1948). Application of nano-N and nano-Zn had a significant effect on dry matter production. Treatment receiving 100 per cent RDN + foliar nano-N + nano-Zn application recorded higher dry matter production at all dates of observations. Application of nano-N and nano-Zn enhanced chlorophyll and increased light interception, absorption and utilization of solar radiation thus enhancing photosynthesis which was reflected in LAI and dry matter production. Due to the higher uptake of nutrients, better source to sink relation and higher translocation of starch, dry matter production was greater with application of nano fertilizers. This finding was in conformity with Lenka and Das (2019). Application of 75 % N through urea and foliar spray of nano-N and nano-Zn increased dry matter. This was due to the use of nanofertilisers as foliar sprays, which boosts the absorption rate and aid in forming high dry matter. Similar findings were observed by Liu and Liao (2008).

Leaf area index (LAI). The data on leaf area index revealed that LAI was significantly influenced by nitrogen levels and method of fertilizer application pooled over two years (Table 3). It was lowest up to 30 days and increased up to 90 DAS and thereafter decreased towards harvest Leaf area index significantly varied at 60, 90 DAS and at harvest by levels of nitrogen.

Application of 100 per cent RDN (3.28, 6.17 and 4.15) recorded higher magnitude of LAI over 75 per cent RDF and was on par with 75 per cent (3.13, 5.91 and 3.94) at 60 DAS, 90 DAS and at harvest, respectively. The lowest LAI was obtained without application of nitrogen (2.26, 4.71 and 2.62) at 60, 90 DAS and at harvest, respectively. LAI was significantly influenced by method of fertilizer application at 60, 90 DAS and at harvest. Greater LAI was seen with foliar application of nano-N and nano-Zn at 35 and 55 DAS (3.20, 6.03 and 3.90) at 60, 90 DAS and at harvest, respectively followed by foliar application of nano-N (2.88, 5.54 and 3.55, respectively). Overall interaction between, nitrogen levels and method of fertilizer application was found significant in all growth stages of crop except at 30 DAS. Combination of 100 per cent RDN along with foliar spray of nano-N and nano-Zn (3.97, 7.20 and 4.82) has recorded significantly higher LAI at 60, 90 DAS and at harvest, respectively and significantly lower LAI was observed with application of only PK (2.04, 4.19 and 2.25, respectively).

Maximum LAI values were observed under 100 per cent RDN was due to sufficient supply of N that produced larger leaves and more number of leaves per hill that has resulted in enhanced photosynthetic surface area. Waqas *et al*. (2017) reported that the greater leaf expansion attributed to higher rate of cell division and cell enlargement thereby higher LAI. Application of 100 per cent RDN along with foliar spray of nano-N and nano-Zn resulted in higher LAI due to more number of leaves and leaf area. This heightened LAI significantly enhanced light interception, fostering more efficient photosynthesis and biomass accumulation. The optimum supply of nutrients through both soil and foliar application has resulted in higher LAI.

Crop growth rate (g m^{-2} day^{-1}). Crop growth rate (CGR) of finger millet was significantly influenced by nitrogen application rates and method of fertilizer application as shown in Fig.1. CGR was lower during the initial crop growth stage (30 DAS), it reached maximum during 61-90 DAS and thereafter declined towards harvest.

Data revealed that CGR increased with growth advancement in age of the crop up to 90 DAS, thereafter, it decreased towards the maturity of the crop. Application of 100 per cent RDN (20.53, 22.25 and 17.21 g m^{-2} day^{-1}) recorded significantly greater CGR at 31-60 DAS, 61-90 DAS and 91 DAS-harvest, respectively than that of 50 per cent RDN (16.57, 21.80 and 10.39 g m^{-2} day^{-1}, respectively) and was on par with 75 per cent RDF (19.47, 21.93 and 16.39 39 g m^{-2} day^{-1}, respectively). Significantly maximum CGR was recorded with foliar application of nano-N and nano-Zn at 31-60 DAS (20.01 g m^{-2} day^{-1}), 61-90 DAS (22.16 g m^{-2} day^{-1}) and 91 DAS-harvest (14.17 g m^{-2} day^{-1}). Application of 100 per cent RDN in conjugation with foliar spray of nano-N and nano-Zn at 35 and 55 DAS (24.43, 22.23 and 17.97 g m^{-2} day^{-1}) recorded significantly larger CGR at 31-60 DAS, 61-90 DAS and 91 DAS-harvest, respectively.

Awais *et al*. (2015) opined that improvement in the CGR was due to more vegetative growth due to increased photosynthesis at higher nitrogen rates and foliar spray of nano-N and nano-Zn. These results validate the findings of Nasim *et al*. (2011) who also indicated the positive effects of nitrogen on CGR of sunflower crop. Mondal *et al*. (2017) reported that greater LAI caused higher light interception which further enhanced CGR in mustard crop.

Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index. The data on grain and straw yield of finger millet influenced by the application of levels of nitrogen and method of fertilizer application were pooled over two years and are presented in Table 4.

The present study revealed that among different nitrogen levels, application of 100 per cent N and recommended PK resulted in significantly higher finger millet grain (3069 kg ha^{-1}) and straw yield (4488 kg ha^{-1}) but was on par with application of 75 per cent nitrogen and recommended PK (2987 and 4343 kg ha^{-1}, respectively). Among different methods of fertilizer application, foliar application of nano nitrogen and nano zinc @ 35 and 55 DAS resulted in significantly higher finger millet grain (2791 kg ha^{-1}) and straw yield (4065 kg ha^{-1}) compared to foliar application of nano nitrogen or nano zinc individually. The interaction effect of 100 per cent nitrogen and recommended PK with foliar spray of nano-N and nano-Zn recorded significantly higher grain yield (3453 kg ha^{-1}) and straw yield (5048 kg ha^{-1}) and was on par with the application of 75 per cent N and recommended PK + foliar spray of nano-N and nano-Zn (3449 and 5035 kg ha^{-1}, respectively) and other treatments in comparison. When conventional fertilizers and nano fertilizers were applied together, higher yield was produced than conventional fertilizers. The lowest grain (1427 kg ha^{-1}) and straw yield (2169 kg ha^{-1}) was found with application of only P and K (control). It was inferred from the data pertaining to harvest index that harvest index showed non-significant effect with respect to the levels of nitrogen and method of fertilizers application.

Application of 100 per cent of nitrogen recorded significantly higher grain and straw yield, but it was on par with the application of 75 per cent nitrogen. The minimum yield was obtained without nitrogen application. Increased nitrogen rates from 0 to 100 per cent RDN significantly enhanced the grain and straw yield. This was mainly due to higher dry matter, leading to higher production and transportation of assimilates to fill the seeds thereby resulting in higher yield McDonald (2002). The lowest grain and straw yield was found with application of only P and K (control-1) due to the imbalanced fertilization.

Table 1: Plant height (cm) at different growth stages as influenced by levels of nitrogen and method of fertilizer application in finger millet.

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Factor A (Nitrogen levels)				
A_1 - N_0	24.48	43.19	70.03	73.78
A_2 - N_{50}	25.62	46.63	76.38	79.35
A_3 - N_{75}	28.08	59.30	86.93	90.68
A_4- N_{100}	29.26	60.95	89.69	93.33
S.Em±	0.86	0.62	0.87	0.93
CD at 5 %	-	1.79	2.51	2.68
Factor B (Method of fertilizer application)				
B_1 - Soil application of Zn	25.60	48.99	76.62	80.33
B_2 – Nano-N	27.19	54.25	81.85	85.32
B_3 – Nano-Zn	26.22	50.42	78.93	82.31
B_4 – Nano-N + Nano-Zn	28.43	56.41	85.62	89.18
S.Em±	0.86	0.62	0.87	0.93
CD at 5 %	-	1.79	2.51	2.68
Interactions (A×B)				
A_1B_1	23.68	42.11	67.71	71.46
A_1B_2	24.70	43.72	70.29	74.74
A_1B_3	24.54	42.78	70.09	73.23
A_1B_4	25.00	44.17	72.01	75.69
A_2B_1	25.16	44.84	73.53	78.12
A_2B_2	25.80	46.90	77.46	80.00
A_2B_3	25.46	45.87	76.44	79.14
A_2B_4	26.05	48.94	78.07	80.13
A_3B_1	26.33	53.01	80.31	83.63
A_3B_2	28.54	63.18	89.74	93.18
A_3B_3	26.68	54.76	81.53	85.50
A_3B_4	30.77	66.24	96.13	100.42
A_4B_1	27.24	56.02	84.95	88.11
A_4B_2	29.72	63.20	89.90	93.35
A_4B_3	28.18	58.28	87.66	91.36
A_4B_4	31.92	66.30	96.28	100.49
S.Em±	1.73	1.24	1.74	1.86
CD at 5 %	-	3.58	5.02	5.37
PK (Control-1)	20.78	41.09	66.72	70.08
NPK (Control-2)	26.88	55.03	84.02	87.45
S.Em±	1.66	1.21	2.08	2.08
CD at 5 %	-	3.48	5.98	5.96

Table 2: Total dry matter production (g hill^{-1}) at different growth stages as influenced by levels of nitrogen and method of fertilizer application in finger millet.

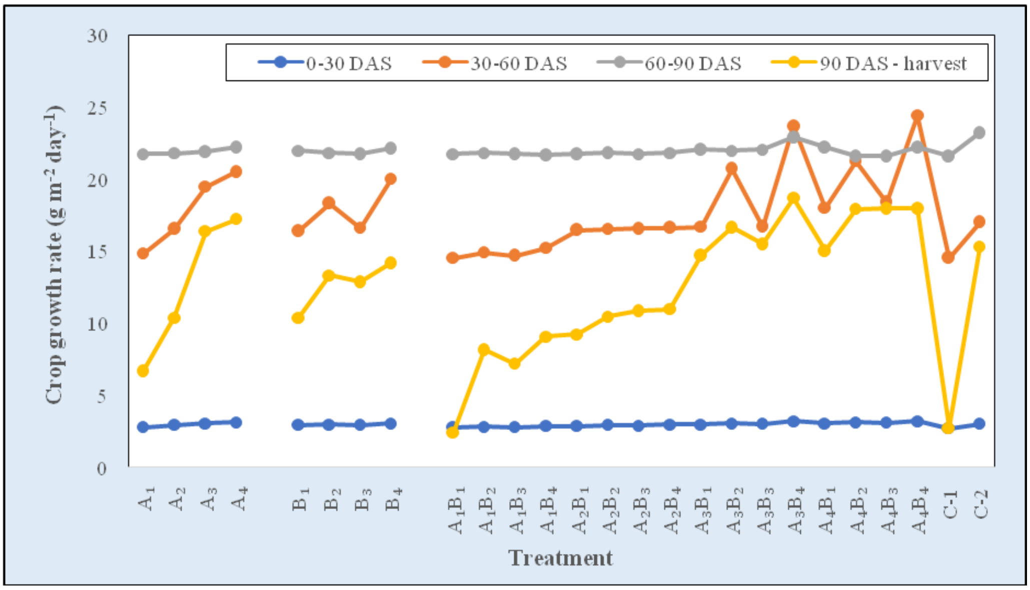
Treatment	30 DAS	60 DAS	90 DAS	At harvest
Factor A (Nitrogen levels)				
A_1 - N_0	2.52	15.88	35.46	40.95
A_2 - N_{50}	2.62	17.53	37.15	46.51
A_3 - N_{75}	2.75	20.27	40.30	55.05
A_4- N_{100}	2.80	21.28	41.09	56.51
S.Em±	0.06	0.51	0.55	0.51
CD at 5 %	NS	1.46	1.59	1.48
Factor B (Method of fertilizer application)				
B_1 - Soil application of Zn	2.63	17.41	37.18	46.44
B_2 – Nano-N	2.68	19.20	38.90	50.81
B_3 – Nano-Zn	2.65	17.60	37.21	48.31
B_4 – Nano-N + Nano-Zn	2.74	20.76	40.70	53.46
S.Em±	0.06	0.51	0.55	0.51
CD at 5 %	NS	1.46	1.59	1.48
Interactions (A×B)				
A_1B_1	2.49	15.58	35.15	37.10
A_1B_2	2.54	15.94	35.57	42.94
A_1B_3	2.51	15.75	35.33	39.83
A_1B_4	2.55	16.27	35.78	43.95
A_2B_1	2.59	17.44	37.05	45.36
A_2B_2	2.63	17.50	37.18	46.60
A_2B_3	2.61	17.54	37.10	46.88
A_2B_4	2.66	17.66	37.30	47.18
A_3B_1	2.68	17.69	37.56	50.83
A_3B_2	2.74	21.41	41.17	56.17
A_3B_3	2.72	17.77	37.60	51.55
A_3B_4	2.88	24.23	44.84	61.64
A_4B_1	2.75	18.94	38.95	52.47
A_4B_2	2.80	21.95	41.70	57.52
A_4B_3	2.77	19.35	38.83	54.99
A_4B_4	2.88	24.87	44.88	61.05
S.Em±	0.13	1.01	1.10	1.03
CD at 5 %	NS	2.93	3.18	2.96
PK (Control-1)	2.44	15.55	35.00	36.84
NPK (Control-2)	2.72	18.04	38.95	52.70
S.Em±	0.13	1.20	1.08	1.02
CD at 5 %	NS	3.44	3.10	2.95

The finger millet grain and straw yield were significantly higher with the foliar application of nano nitrogen and nano zinc @ 35 and 55 DAS compared to foliar application of nano nitrogen and zinc individually. Similar observations were given by Bakhtiari *et al*. (2015); Das and Chakraborty (2018); Lenka and Das (2019). The significant increase in the grain yield observed with the foliar application of nano nutrients was attributed to the improvement in growth parameters and test weight, ultimately leading to an increase in grain yield (Du *et al*., 2011). It was attributed to improved nutrient uptake by the crop leading to the ideal growth of the plant parts and metabolic processes like photosynthesis resulting in maximum photosynthates accumulation and translocation to the economic parts of the plant ensuring higher yield, which attributed to increased source (leaves) and sink (economic part) strength. These findings are in agreement with Liu and Lal (2014); Benzon *et al.* (2015).

Simple linear regression analysis. Although correlation gives information about the nature of relationship that exists between different variables, the significance of the relation and extent is not well defined (Sanam *et al*., 2021). Hence, to quantify the extent of the contribution of different variables to dependent factors like grain yield, linear regression between an explanatory variable and an explained variable is employed. The linear regression between Total dry matter production and yield is shown in Fig. 2.

Table 3: Leaf area index at different growth stages as influenced by levels of nitrogen and method of fertilizer application in finger millet.

Treatment	30 DAS	60 DAS	90 DAS	At harvest
Factor A (Nitrogen levels)				
A_1 - N_0	0.41	2.26	4.71	2.62
A_2 - N_{50}	0.44	2.49	4.99	3.13
A_3 - N_{75}	0.47	3.13	5.91	3.94
A_4- N_{100}	0.48	3.28	6.17	4.15
S.Em±	0.02	0.08	0.13	0.08
CD at 5 %	NS	0.23	0.38	0.22
Factor B (Method of fertilizer application)				
B_1 - Soil application of Zn	0.43	2.49	5.03	3.12
B_2 – Nano-N	0.45	2.88	5.54	3.55
B_3 – Nano-Zn	0.44	2.61	5.18	3.27
B_4 – Nano-N + Nano-Zn	0.48	3.20	6.03	3.90
S.Em±	0.02	0.08	0.13	0.08
CD at 5 %	NS	0.23	0.38	0.22
Interactions (A×B)				
A_1B_1	0.40	2.10	4.55	2.37
A_1B_2	0.42	2.33	4.76	2.72
A_1B_3	0.41	2.24	4.69	2.58
A_1B_4	0.42	2.37	4.83	2.81
A_2B_1	0.44	2.42	4.92	2.99
A_2B_2	0.44	2.52	4.99	3.18
A_2B_3	0.44	2.49	5.00	3.13
A_2B_4	0.45	2.55	5.03	3.20
A_3B_1	0.44	2.61	5.15	3.40
A_3B_2	0.47	3.29	6.13	4.12
A_3B_3	0.44	2.73	5.30	3.48
A_3B_4	0.52	3.90	7.06	4.77
A_4B_1	0.45	2.82	5.50	3.70
A_4B_2	0.49	3.37	6.25	4.18
A_4B_3	0.47	2.97	5.73	3.91
A_4B_4	0.53	3.97	7.20	4.82
S.Em±	0.04	0.16	0.26	0.15
CD at 5 %	NS	0.45	0.75	0.44
PK (Control-1)	0.35	2.04	4.19	2.25
NPK (Control-2)	0.45	2.78	5.40	3.70
S.Em±	0.04	0.16	0.29	0.15
CD at 5 %	NS	0.46	0.83	0.44



Nitrogen levels (A_1: No nitrogen, A_2: 50% RDN, A_3: 75% RDN and A_4: 100% RDN) and method of fertilizer application (B_1: Soil application of zinc, B_2: Foliar application of nano nitrogen @ 35 and 55 DAS, B_3: Foliar application of nano zinc @ 35 and 55 DAS and B_4: Foliar application of nano nitrogen and nano zinc @ 35 and 55 DAS)

Fig. 1. Crop growth rate (g m^{-2} day^{-1}) at 61-90 DAS and 91 DAS- harvest as influenced by levels of nitrogen and method of fertilizer application in finger millet.

Table 4: Grain yield, straw yield and harvest index as influenced by nitrogen levels and method of fertilizer application in finger millet.

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
A_1 - N_0	1701	2486	0.41
A_2 - N_{50}	2188	3227	0.41
A_3 - N_{75}	2987	4343	0.41
A_4- N_{100}	3069	4488	0.40
S.Em±	32	51	0.004
CD at 5 %	93	146	-
B_1 - Soil application of Zn	2226	3265	0.41
B_2 – Nano-N	2573	3714	0.41
B_3 – Nano-Zn	2355	3500	0.40
B_4 – Nano-N + Nano-Zn	2791	4065	0.41
S.Em±	32	51	0.004
CD at 5 %	93	146	-
A_1B_1	1507	2325	0.40
A_1B_2	1720	2478	0.41
A_1B_3	1681	2471	0.41
A_1B_4	1897	2669	0.42
A_2B_1	1979	2743	0.42
A_2B_2	2240	3414	0.40
A_2B_3	2167	3242	0.40
A_2B_4	2365	3508	0.41
A_3B_1	2645	3851	0.41
A_3B_2	3164	4480	0.41
A_3B_3	2689	4007	0.40
A_3B_4	3449	5035	0.41
A_4B_1	2775	4139	0.40
A_4B_2	3166	4482	0.41
A_4B_3	2884	4282	0.40
A_4B_4	3453	5048	0.41
S.Em±	64	101	0.01
CD at 5 %	186	293	-
Control 1	1427	2169	0.39
Control 2	2715	4101	0.40
S.Em±	63	100	0.01
CD at 5 %	182	287	-

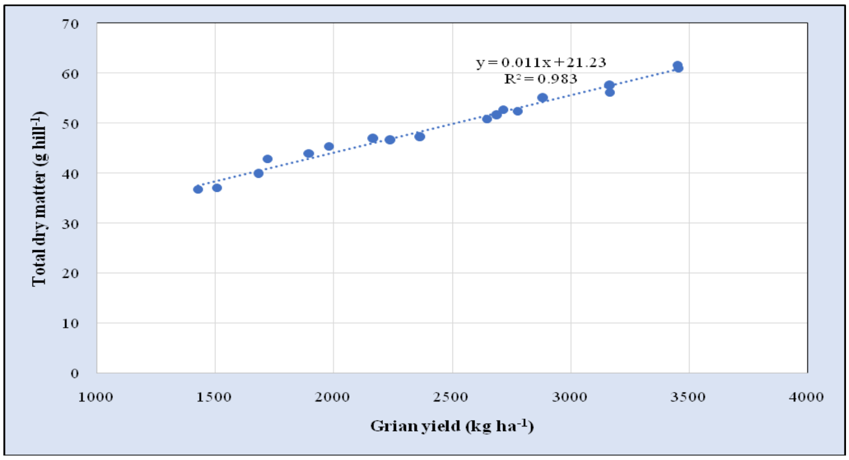


Fig. 2. Simple Linear Regression relationship between yield and nitrogen uptake.

It shows that total dry matter production at harvest has the greatest impact on grain yield when employing different levels of nitrogen and methods of fertilizer application. According to the prediction power, dry matter accounts for 98.3% of grain yield.

CONCLUSIONS

Foliar spray of nano nitrogen and nano zinc proved extremely efficient in increasing growth and yield of finger millet. Application of 100 % RDN along with spraying of nano-N and nano-Zn increased growth parameters and was on par with application of 75% RDN with spraying of nano-N and nano-Zn.

The results of the study revealed that, application of 75% RDN along with foliar application of nano nitrogen and nano zinc @ 2 ml l^{-1} at 35 and 55 DAS recorded higher finger millet grain yield compared to RDF. Thus, application of nutrients matching the crop growth need has increased productivity and also helped to reduce the use of conventional fertilizers.

FUTURE SCOPE

— Need to study the dynamics of nano nitrogen and zinc particles in soil and plant

— Need to develop nano composite to supply all the required essential nutrients in suitable proportion

— Optimization of doses of different nanofertilizers for different crops has to be assessed.

Acknowledgements. This work was supported by AICRP for Dryland Agriculture, University of Agricultural Sciences, Bangalore, Karnataka, India and Department of Science and Technology, Government of Karnataka, India.

Conflict of Interest. None.

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How to cite this article: Sneha M.A., Mudalagiriyappa and Vasanthi B.G. (2023). Response of Finger Millet to Nano Nitrogen and Nano Zinc for Enhancing Productivity. *Biological Forum – An International Journal*, *15*(10): 1470-1477.