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Influence of different PGRs and zinc levels biofortification on nutrient content and uptake in pearl millet under a hyper arid region

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Abstract

A field trial was carried out at the Agronomy farm of OPJS University, Churu (Rajasthan) during the *Kharif* season 2018-19 on loamy soil to find out the influence of different Plant Growth Regulators (PGRs) and Zn levels biofortification application on nutrient content, uptake, quality, and economics. The trial was arranged in RBD (Factorial) along replicated three times, assigning twelve treatments consisting of three PGRs (Triacontanol @ 1000 ppm, NAA @ 50 ppm, & control) and four Zn levels (control, 2, 4, & 6 kg ha^{-1}). The PGRs & Zn levels biofortification application was 20 & 40 DAS in pearl millet crops. Based on the trial outcome Triacontanol and NAA significant progress was noted in nutrient (N, P, & Zn) concentration, uptake in plant, protein contains, net return, & B: C ratio in pearlmillet. Nutrients N, P, & Zn concentration in grain and straw significantly improved from 34.55 & 24.38, 10.39 & 0.18, 26.19 & 18.67, and 75.24 & 48.58, 10.78 & 6.86, 28.10 & 20.94 percent, respectively. The minimum N, P, & Zn concentration in seed and straw was noted in control. Triacontanol & NAA gave significantly higher net return (₹ 54,775 & 50, 906 ha^{-1}) and B: C ratio (3.22 & 3.04) over control. The Zn level application in the biofortification application was found significant in N, P, & Zn concentration and uptake in the plant, protein contains, net returns, and B: C ratio significantly improved with Zn fertilization @ 4 kg Zn/ha over control, which was remained at par with 6 kg Zn/ha. The net return & B: C ratio attained with 4 kg Zn/ha practice were ₹ 51,634/ha and 3.08, respectively.

Keywords: NAA, triacontanol, Zn, plant growth regulators, and nutrient

Introduction

Pearl millet [*Pennisetum glaucum* (L.) is the world's sixth major cereal food crop followed by Rice, Wheat, Corn, Barley, and Sorghum, and India's fourth after Rice, Wheat, and Maize (Alam *et al.*, 2010) [1]. It has an area of around 9.5 MH, production of 11.83 MT, and productivity of 1200 kg/ha worldwide (USDA, 2022) [2, 8]. India has a bigger area of 7.65 MH, production of 10.86 MT, and productivity of 1420 kg/ha reported through 2021-22 (Anonymous, 2022) [3]. The foremost producing states in India like Rajasthan, Gujarat, Haryana, Uttar Pradesh, and Maharashtra contributed 90 percent of total production. Rajasthan stands first in the country producing 5.81 MT from a 4.34 MH area and contributes about 46.67 percent area and 53.50 percent of production in India & with an average productivity of 1338 kg/ha (Anonymous, 2022-23) [4]. In Rajasthan, pearl millet is normally cultivated in unirrigated, highly erratic areas with rainfall receiving from 150 to 600 mm. It is conventionally an arid crop reason its capacity to use water efficiently, heat tolerant to effective in the consumption of solar radiation, high tillering, and drought, adapted to harsh climatic across different soil types. It is a tendency for high dry matter production at high temperatures that has an indication in the tropics and subtropics (Khardia *et al.*, 2020) [17]. It's well adapted to less erratic rainfall conditions, drought-escaping mechanisms, and lower water requirements. Nowadays, it is receiving extra care reason enhancing signals of less periodic rainfall, lethal heat, and recurrent incidence of risky weather events attached to light water resources (Singh *et al.*, 2013) [24]. The practice of plant growth regulators (PGRs) has a better influence on increasing crop yield and quality under the stress environment. Growth regulators are chemical ingredients that can modify the growth, and developmental procedures leading to increased yield, enhanced grain quality, or helped harvesting (Bisht *et al.*, 2020) [8]. In standing crops, the biofortification application of PGRs enhances the drought tolerance of plants reason the specific character of the sulfhydryl group in photosynthesis and dry matter partition. Growth regulators are recognized to show a helpful character in enhancing qualitative and quantitative features in plants. Biofortification application of Triacontanol and naphthalene acetic acid (NAA) has been described to bring physiological effectiveness, with the photosynthetic skill of plants which outcome in better growth, and yield of various crops exclusive of a significant rise in the expenditure of production (Sumeriya *et al.*, 2000) [27]. As in soils and plants, Zn is an important micronutrients desire rather than in minor concentrations (5-100 mg kg^{-1}) for vigorous growth, reproduction of plants, defense against heat stress, and few pathogens (Alloway, 2008) [2]. Zn deficit is a normal nutritional risk in humans, mostly in developing nations, where foods are rich in cereal-founded diet and poor in animal products (Cakmak *et al.*, 1999) [9]. Zn a dynamic character plays in the synthesis of protein, nucleic acid, chlorophyll and supports the consumption of nitrogen and phosphorus by plants as, its performances as an activator of dehydrogenases, protein, and enzymes, directly or indirectly in the synthesis of protein and carbohydrates. Zn is a crucial basic of tryptophan amino acid, which is a forerunner of auxin hormones. Additionally, the availability of zinc decreases with a rise in soil pH. Indian soils are most Zn deficient among all the micronutrients. Biofortification is often careful a short-term treatment to increase micronutrient availability in plant. Foliar nutrient uptake is a means of rapid nutrient supply in plant part, especially when the soil nutrient availability or root activity is reduced. Zinc sulfate ($ZnSO_4$) is the furthermost broadly used reason for its high solubility and minimum cost (Reddy *et al.*, 2021) [20]. Fortification application of nutrient levels and PGRs had a significant effect on plant growth criteria, physiological criteria, yield qualities, grain and stover yield, and nutrient uptake. Hence, the current research is planned to find out the influence of biofortification of different PGRs and Zn levels on nutrient content, uptake quality and economics of pearl millet in hyper-arid conditions.

Materials and Methods

The field trial was carried out at the Agronomy farm of OPJS University, Churu (Rajasthan) during the *Kharif* season 2018-19 on loamy soil of pearl millet crop. This area falls under Agro-climatic Zone II-A which is called the Transitional plain of inland draining of Rajasthan. It is situated between North latitude, 75.34 East longitude, western side is 28.39, and an altitude of 233 meters above mean sea level. The twelve-treatment was comprised of three PGR treatments (control, NAA@ 50 ppm & Triacontanol @1000 ppm,) and four Zn levels (control, 2, 4, & 6 kg /ha) were randomized in a randomized block design (factorial) with repeated three time. The treatments were fixed to several plots by random tables as supported by Fisher (1950) [10]. The pearl millet seed was sown of variety 'RHB-177' in the field. It was sowing as per the standard agronomic package of practices. The biofortification of Triacontanol, NAA, and control and four Zn level treatments respectively were done at 20 & 40 DAS (Day after sowing) utilizing 500-550 liters of water sprayed ha^{-1} (Khardia *et al.*, 2022) [16]. The experiments of grain and stover gathered at harvesting period were first oven-dried and afterward ground by an electrical grinder to a fine power for estimation of N, P, & Zn concentration. Nitrogen concentration in seed and stover was tested by colorimetric method (Snell & Snell, 1949) [26]. With little modification of Nessler's reagent. The P concentration tested by the Vanadomolybdophosphoric yellow colour procedure in the sulphuric acid method (Richards, 1954) [21]. The Zn concentration (ppm) was estimated by using the absorption spectrophotometer (AAS) method (Lindsay & Norwell, 1978) [18]. The protein content of grain was obtained with multiplication factor 6.25 with N content (AOAC, 1960) [5]. The experiment data noted for yield parameters and quality characters to statistical analysis in accord with the 'Analysis of variance' procedure as recommended by Fisher (1950) [10] for RBD. The suitable standard mistake for every of the factors was performed. The significance of variations between treatment influences was calculated by the 'F' test. Critical difference (CD) was performed where the variance was recorded significant at a percent level of significance. To estimate the more valuable treatment, the economics of separate treatments were calculated in terms of net returns (Rs. ha^{-1}) at the beginning of the usual market price.

Results and Discussions

Nitrogen concentration and uptake in grain and stover

PGRs: The biofortification application of Triacontanol and NAA was recorded to enhance the N concentration in grain over the control by 34.55 & 24.38 percent, correspondingly. A consistent improve in stover was recorded to the level of 75.24 & 48.58 percent, correspondingly. The maximum N total uptake was recorded with Triacontanol at par by NAA, but significantly greater to the control by 82.24 & 53.91 percent, respectively. The importance of nutrient uptake by the crop was depending on the increase in the biomass production and nutrients concentration at the cellular level. Then the nutrients concentration is increased by the biofortification of PGRs, the whole biomass production was chiefly approachable to importance of nutrient uptake. The outcome of the current trial is in close conformity with the conclusions of Sivakumar *et al.* (2002) [25], Singh *et al.* (2015) [22], Gurrala *et al.* (2018b) [13] & Gurrala *et al.* (2021) [14] in pearl millet, which noted significant increase in nutrient concentration of several crops reason the use of Triacontanol and NAA.

Zinc fertilization: The fortification application of Zn levels was recorded to enhance the N concentration in pearlmillet grain and stover, then a significant increase was recorded upto 4 kg/ha. The Zn level increased the N concentration by 8.15 & 20.77 percent in grain and 9.94 and 33.87 percent in stover over 2 kg/ha and over control, correspondingly. An additional enhancement in Zn level to 6 kg/ha is represented. The total uptake of N by crop showed greatly was found to increase due to increasing levels of Zn application (Table 1). Application of Zn at 4 kg Zn/ha outcome was noted significantly higher total nitrogen uptake of (65.50 kg N/ha) over application of 2 kg Zn/ha and a lower level but persisted at par with 6 kg/ha. The application of 4 kg Zn/ha improved the uptake of total N by 14.42 and 40.90 percent over application of 2 kg/ha and lower levels, correspondingly. The positive impact of crop Zn application on N concentration can reason the activation of physiological processes due to Zn acting as a catalyst and or co-enzyme. The enhanced N concentration reason Zn may be approved to the superior availability of N under Zn treatments. The better accessibility of N in Zn treatments may be reason on synergetic influence. Prasad *et al.* (2015) [19], Singh *et al.* (2015) [22] & Gurjar *et al.* (2022) [12] had similar findings reported in pearl millet. Increasing the N supply increased the grain yield progressively due to the positive effect of Zn in the development of the reproductive organs of pearl millet.

Phosphorus concentration, uptake in grain and stover

PGRs: The phosphorus concentration in grain and stover of pearl millet was recorded as significantly influenced by Triacontanol & NAA over the control, but the variance between them was found significant. Biofortification application of Triacontanol and NAA improved P concentration in seed over control by 10.39 and 0.18 percent, correspondingly. An improvement in stover was found to the level of 10.78 and 6.86 percent, respectively. The PGRs brought perceptible enhancement in the P total uptake of pearl millet. The maximum total P uptake was recorded with Triacontanol at par with NAA, but significantly excellent to the control by 30.58 & 20.64 percent, respectively. The outcome of the present research is similar conformism with the conclusions of Sivakumar *et al.* (2002) [25], Singh *et al.* (2015) [22], Gurrala *et al.* (2018b) [13] & Gurrala *et al.* (2021) [14] in pearl millet, which recorded significant enhancement in the nutrient concentration of several crops reason the biofortification application of triacontanol and NAA.

Zinc fertilization: The biofortification application Zn level increases the P concentration of pearl millet seed as well as stover, but a significant rise was recorded upto 4 kg/ha. The Zn level improved P concentration by 1.69 & 4.64 percent of seed and 1.92 and 5.77 percent in stover over 2 kg/ha and lower-level control, correspondingly. Added, an improvement in Zn level to 6 kg/ha denoted a statistically parallel nutrient concentration in grain and stover. Total P uptake by the crop listed thoughtful was found to increase due to increasing levels of Zn biofortification application (Table-1). Biofortification application of Zn at 4 kg Zn/ha resulted were recorded significantly higher total P uptake of (10.61 kg N/ha) over 2 kg Zn/ha and lower-level control but remained at par with 6 kg/ha. The application of 4 kg Zn/ha improved the uptake of total P by 6.28 and 15.67 percent over 2 kg/ha and lower-level control, respectively. This might be reasoning the antagonistic influence of Zn on the P concentration. The uptake of P reason the application of Zn increased was found significantly on the lower levels of Zn (2 kg ha^{-1}) but subsequently, the increase was found non-significant. The increase in P uptake was significant only upto 2 kg Zn per ha. These outcomes validate the conclusions of Singh *et al.* (2015) [22], Singh *et al.* (2017) [24], Reddy *et al.* (2021) [20] & Gurjar *et al.* (2022) [12] in pearl millet described a significant increase in nutrient concentration and total uptake reason the application of Zn.

Zinc concentration and uptake in grain and stover

PGRs: Zn concentration in grain and stover of pearl millet was found influenced notably by all the PGRs to over control, although the variance between them was noted as considerable. biofortification application of triacontanol and NAA grew Zn concentration in grain over the control by 26.19 and 18.67 percent, respectively. The consistent rise in stover was found to enhance of 28.10 & 20.94 percent, correspondingly. The PGRs were noted to significantly enhance the Zn uptake by pearl millet. The biofortification application of Triacontanol and NAA were found statistically at par but significantly enhanced the Zn uptake over water sprayed to the extent of 49.29 & 35.13 percent, respectively. The outcome of the present research is in near conformity with the conclusion of Sivakumar *et al.* (2002) [25], Singh *et al.* (2015) [22], & Gurrala *et al.* (2018b) [13] in pearl millet, which noted considerable improvement in the nutrient concentration of several crops reason the biofortification application of triacontanol & NAA.

Zinc fertilization: The biofortification application of Zn at 4 kg/ha was found to significantly enhance the Zn concentration in grain and stover of pearl millet over the 2 kg Zn/ha and lower-level control, then it was recorded at par with 6 kg/ha (Table 1). The greatest concentration in grain (35.91 ppm) and stover (25.14 ppm) were noted under 6 kg Zn/ha. The biofortification application of Zn at 4 kg Zn/ha raised the Zn concentration by 1.98 and 7.25 percent in grain and 2.49 and 10.09 percent in straw over 2 kg Zn/ha and lower-level control, correspondingly. Hence, effective Zn concentration was noted as 4 kg/ha Zinc application. A lower level @ 4 kg Zn/ha significantly increased total Zn uptake over 2 kg Zn/ha and control but remains at par with 6 kg Zn/ha. The biofortification application of Zn at 4 and 6 kg/ha was found to increase the uptake of Zn by 194.64 and 205.23 kg/ha and the percent increased by 19.72 and 26.24 over lower-level control and 2 kg/ha, correspondingly. This can be characteristic to be rise in the Zn concentration in the plant solution, which give rise to in increasing intake of the nutrient from the biofortification direct to plant and consequently increased Zn concentration in seed and stover was due to increasing plant growth and changing pH around the root zone and positively root uptake, shoot translocation. While uptake was the role of nutrient concentration in seed & stover and their relevant yields. These outcomes validate conclusions of Prasad *et al.* (2015) [19], Singh *et al.* (2015) [22], Gurjar *et al.* (2022) [12] & Asodariya *et al.* (2023) [7] in pearl millet.

Zinc uptake in grain and stover

PGRs: Zn uptake in seed and stover of pearl millet was found notably influenced by all the PGRs over the control, then the variance between them was found to be noted as significant (Table 2). The biofortification application of triacontanol and NAA increased Zn uptake in seed over the control by 55.37 and 38.27 percent, correspondingly. The consistent raise in stover was to the limit of 45.95 and 33.41 percent, correspondingly. The outcome of the present experiment is in near conformity with the conclusions of Singh *et al.* (2015) [22] & Gurrala *et al.* (2021) [14] in pearl millet.

Zinc fertilization: The biofortification application of enhancing levels of Zn increases the Zn uptake of pearl millet seed as well as stover, but a pointed increase was recorded upto 4 kg/ha, only. The Zn levels increased Zn uptake by 9.16 and 22.39 percent of seed and 5.52 and 18.27 percent in stover over 2 kg/ha and lower-level control, correspondingly. Additionally, an raise in Zn level to 6 kg/ha corresponded to statistically parallel nutrient Zn uptake in grain and stover. A similar outcome was also described by Prasad *et al.* (2015) [19], Singh *et al.* (2015) [22], Reddy *et al.* (2021) [20], Gurjar *et al.* (2022) [12] & Asodariya *et al.* (2023) [7] in pearl millet. As both the content and yields enhanced thus the total uptake of Zn enhanced notably with the biofortification application of Zn. The positive function of Zn in increasing the CEC of roots facilitated in increasing the absorption of nutrients from the plant and might have also increased Zn uptake.

Protein content in grain

PGRs: The protein content in the grain of pearl millet was found influenced considerably by all the PGRs over the control, although the variance between them was found significant. The biofortification application of triacontanol and NAA improved protein content in grain over the control by 26.74 & 19.74 percent, correspondingly. The outcomes of the current experiment are in near conformism with the conclusions of Singh *et al.* (2015) [22] & Gurrala *et al.* (2021) [14] in pearl millet, which found important improvement in the protein content of various crops reason the biofortification application of triacontanol and NAA.

Zinc fertilization: The biofortification application of Zn at 4 kg Zn/ha considerably enhanced the protein content in grain over the highest noted levels (Table 2). Application of 6 kg Zn/ha showed 10.02 percent protein in seed thus raising it to the extent of 4.87 and 11.46 percent over the 2 kg/ha and lower-level control, separately. The biofortification application of 6 kg Zn/ha persisted and was recorded at par with 4 kg Zn/ha. A similar outcome was also described by Prasad *et al.* (2015) [19], Singh *et al.* (2015) [22], Gurjar *et al.* (2022) [12] & Asodariya *et al.* (2023) [7] showed that Zn in improving levels upto 4 kg ha^{-1} was confirmed to significantly increase the plant Zn concentration in seed and stover and protein content in seed over control. While uptake was the behavior of nutrient concentration in seed and stover and their relevant yield.

Effect of Economic

Net return

PGRs: The biofortification application of PGRs continued triacontanol at par with NAA was provided extensively more net return per hectare of pearl millet by ₹ 54,775 & ₹ 50,906 over control respectively. It was noted percent increases in net return per hectare of pearl millet 19.90 & 29.01 control (Table 3). The biofortification application of NAA and triacontanol was noted to increase the net return and B: C ratio over the control (4.14). The expense of these PGRs was low in contrast to the enhanced output, thus, the increased seed yield led to increased net returns. Present outcomes are in near conformism with those of Gurrala *et al.* (2018b) [13] & Ganesh and Debbarma (2023) [11] reported that the effects of PGRs on the economics of pearl millet enhance higher net returns and B: C ratio.

Zinc fertilization: The biofortification application of Zn with enhancing levels upto 4 kg ha^{-1} was noted to considerably enhance the net return per hectare by Rs 47,925 & Rs 51,634 over control and 2 kg Zn, respectively. It recorded percent increases in net return per hectare of pearl millet 7.14 and 15.43 over control (Table 3). The cost of increased yield was found much more than the cost of the Zinc application which increased the net returns and B: C ratio. These outcomes are corroborated by the conclusions of Arshewar *et al.* (2018) [6] & Reddy *et al,* (2021) [20] who also reported that Zn concentration and uptake in the plant, net returns.

Benefit: Cost ratio

PGRs: The biofortification application PGRs was found to significantly increase the B: C ratio over control, but the effect of triacontanol and NAA was found at par with each other. The maximum B: C ratio was recorded under triacontanol (3.22) significantly higher over (3.04) and control (2.73). NAA also enhanced the B: C ratio as contrasted to the control. It is a necessary plant nutrient; it is involved in many physiological processes that increase grain yield resulting in a higher benefit-cost ratio. It is a percent increase B: C ratio per hectare of pearl millet 11.36 and 17.96 over control. Similar outcomes were described by Ganesh & Debbarma (2023) [11].

Zinc fertilization: The sequential accumulation in ranked levels of Zn outcome in a considerably higher B: C ratio upto 4 kg/ha over the lower level. The B: C ratio (3.09) was noted at 4 kg Zn/ha which was at par (3.12) with 6 kg Zn/ha. It was found percent increase B: C ratio hectare of pearl millet was 4.32 and 9.17 over control. It might be recognized to increased grain and stover yields with Zn application. The B: C ratio was confirmed to significantly increase with Zn fertilization @ 4 kg Zn /ha over control, which persisted at par with 6 kg Zn /ha. Such types of results were also described by Arshewar *et al.* (2018) [6], Gurrala *et al.* (2018b) [13] & Reddy *et al.* (2021) [20] in pearl millet told a considerable enhancement in economics reason to the application of Zn.

Table 1: Effect of plant growth regulator and Zink biofortification on different nutrient concentrations and uptake of pearl millet.

Treatments	Nitrogen concentration (%)		Phosphorus concentration (%)		Zinc concentration (%)		Total N uptake (kg ha^{-1})	Total P uptake (kg ha^{-1})	Total Zinc uptake (ppm/ha^{-1})
	Grain	Stover	Grain	Stover	Grain	Stover			
PGRs									
NAA	1.501	0.630	0.247	0.109	34.761	24.574	62.263	10.444	194.067
Triacontanol	1.628	0.743	0.255	0.113	36.966	26.029	73.724	11.304	214.388
Water spray	1.210	0.424	0.231	0.102	29.293	20.319	40.454	8.657	143.620
SEm±	0.005	0.001	0.001	0.000	0.123	0.024	0.328	0.050	0.941
C.D.(p=0.05)	0.016	0.003	0.002	0.001	0.362	0.072	0.968	0.148	2.777
Zinc levels (kg /ha)									
0	1.276	0.493	0.237	0.104	31.943	22.210	46.486	9.173	162.580
2	1.380	0.542	0.241	0.106	32.576	22.763	53.189	9.749	173.642
4	1.541	0.660	0.248	0.110	34.260	24.450	65.499	10.610	194.644
6	1.594	0.700	0.251	0.111	35.914	25.140	70.081	11.007	205.233
SEm±	0.006	0.001	0.001	0.001	0.142	0.028	0.379	0.058	1.086
C.D.(p=0.05)	0.019	0.003	0.002	0.001	0.418	0.083	1.118	0.171	3.207
Factor (A x B)									
SEm±	0.011	0.002	0.001	0.001	0.245	0.049	0.656	0.101	1.881
C.D.(p=0.05)	0.032	0.006	0.004	0.003	0.724	O.143	1.936	0.297	5.554

Table 2: Effect of PGRs and zinc on grain and stover zinc uptake (ppm) and protein content by pearl millet

Treatments	Zinc uptake (ppm)		Protein Contain percent
	Grain (ppm)	Stover (ppm)	
PGRs			
NAA	70.16	123.90	9.74
Triacontanol	78.84	135.55	10.31
Water spray (control)	50.74	92.88	8.14
SEm±	0.25	0.93	0.01
C.D.(p=0.05)	0.73	2.73	0.01
Zinc levels (kg /ha)			
0	57.38	105.20	8.71
2	62.64	111.01	9.14
4	70.23	124.41	9.71
6	76.07	129.16	10.02
SEm±	0.29	1.07	0.01
C.D.(p=0.05)	0.84	3.15	0.01
Factor (A x B)			
SEm±	0.49	1.85	0.01
C.D.(p=0.05)	1.46	5.46	0.02

NS =Non significant

Table 3: Effect of PGRs and zinc on net returns and B: C ratio of pearl millet

Treatments	Economic analysis	
	Net returns (₹ ha^{-1})	(B: C) ratio
PGRs		
NAA	50,906	3.04
Triacontanol	54,775	3.22
Water spray (control)	42,458	2.73
SEm±	241	0.01
C.D.(p=0.05)	713	0.03
Zinc levels (kg /ha)		
0	44,732	2.82
2	47,925	2.95
4	51,634	3.08
6	53,230	3.13
SEm±	279	0.01
C.D.(p=0.05)	823	0.03
Factor (A x B)		
SEm±	483	0.02
C.D.(p=0.05)	1425	0.06

NS =Non significant

Conclusion

The biofortification application of PGRs and Zn was significantly influencing the nutrient concentration, uptake and economics of pearl millet. The most suitable PGRs as it provided net returns (₹ 54775 /ha), BCR (3.21) from pearlmillet which was comparable to control. The biofortification application of 4 kg Zn/ha is superior to obtained significantly net return (₹ 51634/ha) and B: C ratio (3.08) of pearlmillet. Other new PGRs should be tested to validate present results and to compare their effectiveness in PGRs.

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