Effect of Nano-Fertilizers, Organic Manure and Biofertilizers in Improved Efficacy of Pearl Millet (*Pennisetum Glaucum*) Productivity, Benefit Cost Ratio and Quality of Grains

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Abstract- The application of nano-fertilizers such as nano-urea and nano DAP in the agricultural field has emerged as a promising strategy for improving the nutritional quality and quantity of grain yield. This study was aimed to determine the effect of foliar applications of nano-urea and nano-DAP in combination with vermicompost and biofertilizers on the crop pearl millet (*Pennisetum glaucum*) grains for the years 2023 and 2024. The study was also focussed on improving the nutritional value of carbohydrates, total calories from fats, total protein content, and fats and the benefit cost ratio of the pearl millet grain yield. The significant increase in the yield and nutrient content was found to be increased in the treatment groups where organic manure, biofertilizers and nano-fertilizers were applied as compared to control (RDF). The experiment was conducted in the Rewari district of Haryana, India. Significant outcomes in terms of net return were recorded in the treatments which included 25% NP + 100% K + two foliar spray @ 5 ml/lt of Nano urea and 2.5 ml /lt Nano DAP and 50% NP + 100% K + two foliar spray @ 5ml/lt of Nano urea and 2.5 ml /lt Nano DAP. The total protein and fats content were found to be highest and increased in the treatment group including Vermi compost @ 2.5 t/ha + seed treatment with bio fertilizer + two foliar spray @ 5ml/lt of Nano urea and 2.5 ml /lt Nano DAP. Therefore, with minimal impact on the environment and efficient nutrient utilization, the nano-fertilizer treatments performed better than traditional fertilizers in enhancing grain quality. In accordance to these results, utilizing nano-fertilizer can significantly improve pearl millet's nutritional profile, boosting sustainable agriculture and ensuring food security.

Keywords: nano-urea, nano DAP, pearl millet, mineral absorption, qualitative analysis, economy and benefit cost ratio.

I. INTRODUCTION

Pearl millet contains abundant amount of calcium, phosphorus, iron, riboflavin and carbohydrates which serves as a staple food for millions of individuals in the dry and semi-arid tropical regions. It also has a significant potential as a crop for forage and feed as well [1]. With a higher protein and calorie content, pearl millet is a more nutrient-dense cereal crop than sorghum as a fundamental human diet. Mustafa. Et al., 2010 [2] reported that pearl millet grain may replace up to 30% of the diet in dairy cow diets without showcasing un-favourable effect on milk composition or yield. Furthermore, chronic malnutrition affects a sizable portion of the population in developing nations where pearl millet is a staple crop. Therefore, increasing grain yield and

improving the nutritional content of pearl millet grain may help combat malnutrition in developing countries like India [3]. Moreover, in the era of commercial fertilizer and limiting environmental conditions, crop pearl millet is widely considered as successful cereal and a major source of nutrition. However, the crop productivity and nutrients content has been significantly reduced due to over usage of harmful fertilizers, pesticides and insecticides. In addition to this, overutilization of chemical fertilizers without organic farming practices has intensified multi-nutrients deficiencies in plant-soil relationship and created an environmental havoc in agriculture system [4]. To overcome, the challenges associated with synthetic fertilizers, soil and water pollution, nutrient-deficit cereal crops and high-cost input of farmers, new technologies such as nano-agriculture, precision farming, multi-cropping system and bio-fertilizer enabled agricultural inputs could be taken into consideration. The expansion and positive effects of nano fertilizers in improving crop growth, yield, and nutrient efficiency are now being studied tremendously in recent research works due to ultra-small size of nanoparticles and high surface area for better penetration and absorption when applied as a foliar spray [5]. Therefore, nanoparticles/nano fertilizers underscore great potential in reducing nutrient wastage, enhancing crop nutrient content and crop quality while addressing environmental concerns. Additionally, beneficial impact of organic manures, vermicompost and biofertilizers on improved soil fertility, microbial community and advocating organic carbon with higher nutrient concentrations efficaciously act as growth regulators for crops [6]. Therefore, this research work was conducted to explore the effects of nano-fertilizers (nano-urea and nano DAP) in combination with organic manure and biofertilizers on the crop Pearl millet to enhance nutrient content, crop yield and grain quality. The experiment was conducted during two consecutive years 2023 and 2024 in the Rewari district of Haryana, India.

II.MATERIALS AND METHODS

2.1 Trial locations and experimental design-

Frontline demonstrations were conducted in Randomized Complete Block Design (RBD) at Rewari District (28.18 °N, 76.58 °E) Haryana, India during the two consecutive years 2023 and 2024 on the crop Pearl millet. The experiment was laid down in three replications with nine treatment groups with a plot size of 20 m^2, plant spacing of 12 cm and row spacing at 45 cm. On-farm experiment was laid out in with nine treatment combinations and replicated three times. The seeds variety chosen for the experiment (HHB-272) for the crop pearl millet was procured from the local seed market.

2.2 Treatment details-

There was total nine treatment groups applied in the field. Treatment 1 was considered as control with 100 % NPK kg ha-1 (150:60:30). Treatment group 2 included NP at 25% with 100% K and two foliar applications of Nano urea and Nano DAP at 4ml and 2.5 ml respectively. Treatment group 3 included NP at 25% with 100% K and two foliar application Nano urea and Nano DAP 5ml and 2.5 ml respectively. Treatment group 4 included NP at 50% with 100% K with two foliar applications of Nano urea and Nano DAP at 4ml and 2.5 ml respectively. Treatment group 5 included NP at 50% with 100% K with two foliar applications of Nano urea and Nano DAP at 5ml and 2.5 ml respectively. Treatment group 6 included NP at 75% with 100% K and two foliar applications of Nano urea and Nano DAP at 4ml and 2.5 ml respectively. Treatment group 7 included NP at 75% with 100% K and two foliar applications of Nano urea and Nano DAP at 5ml and 2.5 ml respectively. Treatment group 8 included 2.5 t/ha Vermi compost and seed treatment with bio fertilizer with two foliar applications of Nano urea and Nano DAP 4ml and 2.5 ml respectively. Treatment group 9 included 2.5 t/ha Vermi compost and seed treatment with bio fertilizer and two foliar applications of Nano urea and Nano DAP at 5ml and 2.5ml respectively.

2.3 Crop yield and economics-

Crop grain yield in ton/hectare and for the both the years, cost of cultivation (CC) gross returns (GR), net returns (NR) and benefit cost ratio (B:C) were calculated for each treatment groups on the basis cost incurred on inputs including seeds, expenses for labour, fertilizers and harvesting and threshing. Net returns were calculated by using the formula Net returns (INR) = Gross returns − Cost of cultivation and benefit cost ratio was calculated by dividing net returns by cost of cultivation [7].

2.4 Qualitative analysis-

For the qualitative parameters of pearl millet crop, total calories, total carbohydrates, total fats and total proteins were estimated. All the qualitative analysis were analysed in the FSSAI approved laboratory following the test method for total calories (JL/CS/STP/015), total carbohydrates (IS 11536 2007 RA:2019), total fats (IS 4684 1975 RA: 2020) and total proteins (IS 729: 1973 RA: 2020) [8].

2.5 Statistical analysis –

All the statistical analysis of the observed outcomes were performed using Microsoft Excel V.16.49 software. ANOVA was applied at significant values $p<0.05$ to compare the significant difference among treated groups.

III.RESULTS

3.1 Crop yield and economics –

For the year 2023, the expected yield for the control (treatment group 1) was recorded 2.38 t/ha. It was increased by 0.42% in treatment group 4, 8.40% in treatment group 7 and 15.12% in treatment group 9 and has been depicted in the table I. For the year 2024, the expected yield was found to be 2.37 t/ha in case of T1 (control) and was increased by 3.37%, 8.07% and 20.25% in treatment groups T4, T7 and T9 respectively. Among all the treatment groups, yield was found to be highest in T9. All the observations were statistically significant. During the economic analysis, net return for T 1 as found to be 41740 Rs/ha and 37390 Rs/hac for the years 2023 and 2024 respectively. It was increased by 7.31% and 8.43% for the year 2023 and 2024 for the treatment group 4. In the treatment group 7 the net return was found to be increased by 6.51% and 12.11% for the year 2023 and 2024 respectively. However, the expected net return was reduced by 5.60% for the year 2023 and was increased by 7.78% for the year 2024. Following the benefit cost (B:C) ratio of 2.46 for the year 2023 and 2.20 for the year 2024 in the treatment group 1 (control). The B:C ratio was recorded 2.60 and 2.34 for the year 2023 and 2024 respectively in the treatment group 4. In the treatment group 7, B:C ratio for the year 2023 was found to be 2.51 and 2.31 for the year 2024. It was recorded 2.01 for the year 2023 and 1.97 for the year 2024 in the treatment group 9.

Table I: The economic parameters of the crop pearl millet showing the total cost of cultivation (Rs/ha), gross return, net return and the B:C ration for both the years 2023 and 2024.

Treatments	**Cost of Cultivation (Rs/ha)**		**Gross Return (Rs/ha)**		**Net Return (Rs/ha)**		**B:C Ratio**	
	Years							
	2023	**2024**	**2023**	**2024**	**2023**	**2024**	**2023**	**2024**
100% NPK	28410	30910	70150	68300	41740	37390	2.46	2.20
25% NP + 100% K + two foliar spray @ 4 ml/lt of Nano urea and 2.5 ml /lt Nano DAP	26002	28502	69350	69125	43348	40623	2.66	2.42
25% NP + 100% K + two foliar spray @ 5 ml/lt of Nano urea and 2.5 ml /lt Nano DAP	26227	28727	70975	69450	44748	40723	2.70	2.41
50% NP + 100% K + two foliar spray @ 4 ml/lt of Nano urea and 2.5 ml /lt Nano DAP	27605	30105	71800	70650	44195	40545	2.60	2.34
50% NP + 100% K + two foliar spray @ 5ml/lt of Nano urea and 2.5 ml /lt Nano DAP	27830	30330	72925	71550	45095	41220	2.62	2.35
75% NP + 100% K + two foliar spray @ 4 ml/lt of Nano urea and 2.5 ml /lt Nano DAP	29207	31707	72550	72725	43343	41018	2.48	2.29
75% NP + 100% K + two foliar spray @ 5ml/lt of Nano urea and 2.5 ml /lt Nano DAP	29432	31932	73875	73850	44443	41918	2.51	2.31
Vermi compost @ 2.5 t/ha + seed treatment with bio fertilizer + two foliar spray @ 4 ml/lt of Nano urea and 2.5 ml /lt Nano DAP	38600	41100	75025	80525	36425	39425	1.94	1.95
Vermi compost @ 2.5 t/ha + seed treatment with bio fertilizer + two foliar spray @ 5ml/lt of Nano urea and 2.5 ml /lt Nano DAP	38825	41325	78225	81625	39400	40300	2.01	1.97

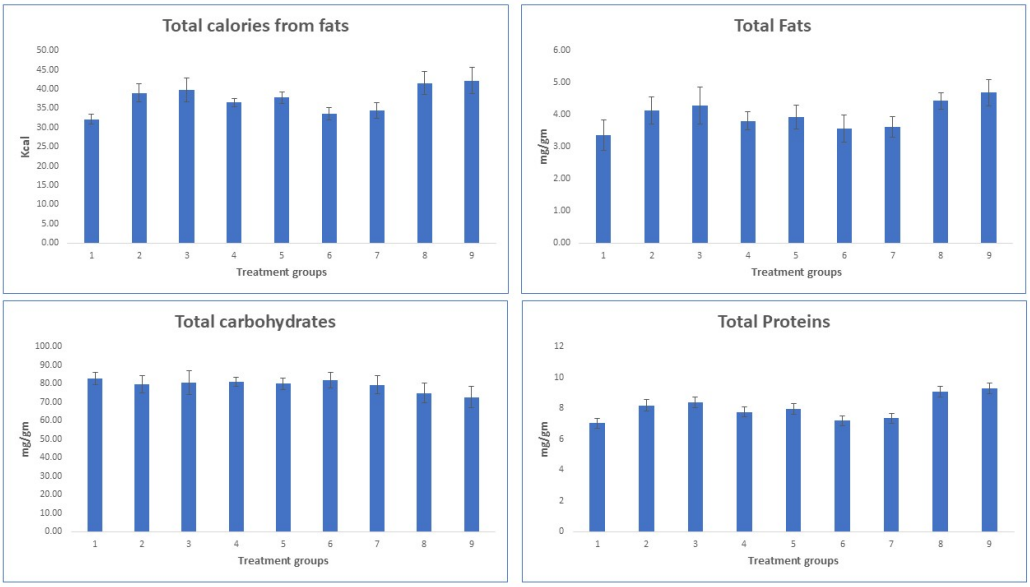

Figure1: Illustration of the quality parameters of the pearl millet crop grain showing total calories from fats (kcal), total fats (mg/gm), total carbohydrates (mg/gm) and total protein (mg/gm) for the year 2023.

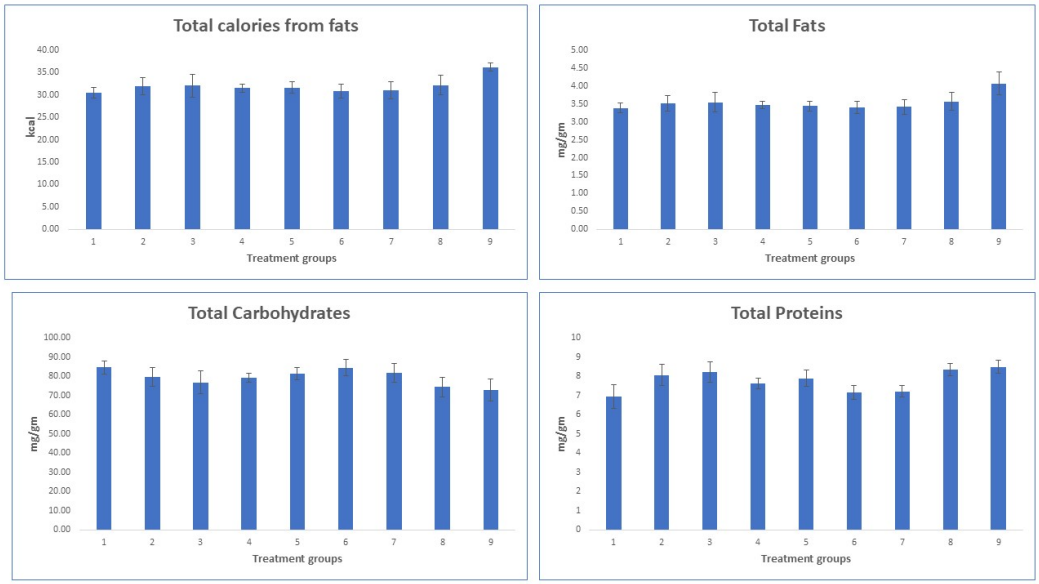

Figure II: Illustration of the quality parameters of the pearl millet crop grain showing total calories from fats (kcal), total fats (mg/gm), total carbohydrates (mg/gm) and total protein (mg/gm) for the year 2024.

3.2 Qualitative analysis-

Total carbohydrates, total calories from fats, total fats and total protein content present in the pearl millet grain were estimated and found to be significant for all the treated groups and have been shown in the figures I and II. For the control group total carbohydrates were recorded 84.60 mg/g for the year 2023 and 82.62 mg/g for the year 2024. Total calories from fats were recorded 30.51 kcal and 32.13 kcal for the years 2023 and 2024 respectively in the control. Total fats were found to be 3.39 mg/g for the year 2023 and 3.37 mg/g for the year 2024. Total proteins were recorded 6.94 mg/g and 7.02 mg/g for the years 2023 and 2024 respectively in the control. Data observed from the carbohydrates estimation in treatment group 4 showed a significant increase of 6.31% and 1.79% for the years 2023 and 2024 respectively. In the treatment group 7 it was increased by 3.26% and 3.94% for the years 2023 and 2024. For the treatment group 9 the carbohydrates content was found to be increased by 13.87% and 12.17% for both the years. The calories from fats were recorded at an increase of 3.44% and 13.53% in the treatment group 4 compared to control. In treatment group 7 it was increased by

1.73% and 7.0% for the years 2023 and 2024 respectively. In the treatment group 9 calories were increased by 18.68% and 31.37% for the years 2023 and 2024. The total fat content has shown an increase of 2.65% and 13.05% for the years 2023 and 2024 in the treatment group 4, whereas was increased by 0.88% and 7.41% in the treatment group 7. The calories were increased by 20.05% and 39.16% in the treatment group 9 for the respective years 2023 and 2024. Total protein content was increased by 9.79% and 10.54% in the treatment group 4 as compared to control. Whereas, an increase of 3.89% and 4.27% was recorded for the treatment group 7 for both the years. The total protein content in the pearl millet grains were increased by 22.19% for the year 2023 and 32.33% for the year 2024 in the treatment group 9.

IV. DISCUSSION

Among the various interaction and treatment combinations, the experimental result depicts the significance of organic manure, biofertilizers and nano fertilizers on the crop pearl millet for the two years 2023 and 2024. The significant agronomic and financial benefits of mixing organic manure, biofertilizers, and nano-fertilizers in pearl millet agriculture, especially in rain-fed and semi-arid environments, have been highlighted by numerous expanding bodies of research work. A Study by Neeraj Yadav (2013) [9] have shown that pearl millet's growth, production, and nutrient uptake are much improved by co-applying 60 kg N + 45 kg P O kg/ha with biofertilizers as compared to conventional methods of agricultural practices. More recently, Karwot et al. (2024) [10] reported that by applying 25% N via poultry manure in combination with 75% N (urea) yielded superior plant height and grain yield (2.46 t/ha). Underscoring the key synergistic effects of organic manures and biofertilizer-mediated microbial facilitation, our research work demonstrated the positive outcomes and increased yield as well as quality parameters of the crop pearl millet in the treatment groups including vermicompost, biofertilizer and foliar applications of nano urea and nano DAP (T8 and T9). In addition to this, Arya et al. (2022) [11] reported improvement in the grain yield of pearl millet under summer conditions by the foliar application of nano-urea. Similarly, Sharma et al. (2022) [12] recorded enhanced nutrient content when foliar application was conducted in the pearl millet. In our study, the treatment groups (T 2, T 3, T 5) tremendously improved the quality of the pearl millet grains where, 25% and 50% of the conventional urea was reduced and application of nano-fertilizers were provided at 4ml/L and 5 ml/L concentrations of nano urea and 2.5 ml/L concentration of nano- DAP as compared to the control. In other treatment groups (T8 and T9), where the combination of organic manure, biofertilizers and nano-fertilizers eliminating the application of NPK, the total calories from fats, fats and protein were found to be higher among all. This could be explained by the improving soil structure ad water holding capacity of the soil improved by providing the organic manure and biofertilizers [13]. Moreover, nano urea and nano DAP offered a controlled delivery mechanism to the plant by enhancing absorption efficiency, reducing volatilization and leaching losses [14-16]. In case of economic factors, the net returns were found to be increased in the treatment groups where nano-fertilizers were applied. However, for the treatment groups (T8 and T9), the net return and B:C ratio were lower than the control for the year 2023 than control, but was increased by 7.78% for the year 2024. Our research work coherently supports the integrated management technique for nutrient absorption and quality improvement and support sustainable intensification of pearl millet cultivation in resource-limited areas.

V. CONCLUSION

In conclusion, the combined applications of nano-fertilizers (nano urea and nano DAP) with organic manures and biofertilizers has shown significant potential in enhancing the crop grain yield and economic viability of pearl millet as compared to conventional fertilization methods. The economic parameters such as benefit-cost ratio and input-use efficiency are favourably influenced by nano-fertilizer-based treatments and has been depicted in our research work. Further, the multi-location trials should be conducted to optimize the concentrations and combinations of nano urea, nano DAP, and bio-organic inputs under various climatic conditions. This research work also highlighted the potential of the treatment combinations derived from nano-fertilizers in improving the quality of the food grains which was found to be highest in the treatment group 9. Therefore, the long-term, eco-toxicity-aware field trials and quality assessment would be essential to mainstream the profitable pearl millet production.

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