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EFFECT OF DIFFERENT FERTILITY LEVELS ON YIELD AND ECONOMICS OF MINOR MILLETS

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ABSTRACT

Minor millets are ancient cereal crops belonging to the Poaceae family, showing possible suitability for cultivation in arid and semi-arid tracts. Their growth is of short duration, showing resistance to insects and tolerance to adverse climatic conditions. The extent used to grow minor millets in India has declined noticeably in the recent decades because of the current cultural choice towards growing major cereal crops, though minor millets contain enormous nutritional as well as agronomic benefits. To improve millet productivity, implementation of sound nutrient management techniques with a special emphasis on nitrogen (N) and phosphorus (P) application is essential for optimal growth as well as yield results. This study sought to evaluate the yield and economic returns of minor millets under different nitrogen and phosphorus application levels. Specifically, the study was laid out in split plot design to analyze four levels of various minor millets: Foxtail millet (SIA3156), Barnyard millet (VL207), Proso millet (TNAU202), and Finger millet (GPU67) designated as main plots. Additionally, four levels of nitrogen and phosphorus are applied in sub-plots, categorized as $N_0 + P_0$, $N_{20} + P_{10}$, $N_{40} + P_{20}$, and $N_{60} + P_{30}$ kg ha^{-1}. The recorded data included yield attributes such as Number of effective tillers (mrl^{-1}), Number of grains ear head^{-1}, Test weight (g), Grain yield (kg ha^{-1}), Stover yield (kg ha^{-1}), Biological yield (kg ha^{-1}) and Harvest Index (%), whereas economic analysis per treatment was done by calculating the gross return (Rs. ha^{-1}), net return (Rs. ha^{-1}) and B:C ratio. The results showed that Foxtail millet (SIA 3156) recorded maximum grain yield (1917 kg ha^{-1}), net returns (Rs. 27,486 ha^{-1}) and a benefit-cost ratio (1.84), making it the most remunerative among the millets. Nutrient dose of 60:30 kg NP ha^{-1} (T_4) had a significantly higher yield (2063 kg ha^{-1}), and economic net return (Rs. 26819 ha^{-1}). Proso millet showed poorest economic performance despite showing more desirable test weight and earhead length might be due to heavy grain shattering and lodging at maturity.

***Key words*:** Economics, Minor millets, Nitrogen, Phosphorus, Yield attributes, Yield.

Introduction

Minor millets are cereal crops that were cultivated over 5,000 years ago and are members of the Poaceae family, a vegetation with tiny grains. Rajasthan, Uttar Pradesh, and Karnataka are the primary cultivation regions in India under arid and semi-dry conditions (Das *et al.*, 2019). Among the 11 identified minor millet species, the following are recognized for their adaptability to challenging climatic conditions: finger millet (*Eleusine coracana* L.), foxtail millet (*Setaria italica* L.), barnyard millet (*Echinochloa* spp.), little millet (*Panicum sumatrense* L.), proso millet (*Panicum miliaceum* L.), kodo millet (*Paspalum scrobiculatum* L.), fonio millet (*Digitaria exilis* L.), teff (*Eragrostis tef* (Zucc.) Trotter), brown top millet (*Urochloa ramose* L.), Job's tears (*Coix lacryma-jobi*), and guinea millet (*Urochloa deflexa*). These species have a characteristic 70 to 80 days short growing season and are resistant to pests and diseases (Devi *et al.*, 2014; Macauley and Ramadjita, 2015; Dhaka *et al.*, 2023).

The largest area used for minor millets cultivation in Madhya Pradesh is 1.65 lakh hectares. Chhattisgarh and Uttarakhand contribute around 0.48 lakh hectares to these millets. Madhya Pradesh produced the highest amount, which was 147,000 tons. Uttarakhand came next with a production of 60,000 tons, and Tamil Nadu produced

33,000 tonnes. The highest productivity achieved is 2321 kg per hectare in Gujarat, followed by 1503 kg per hectare in Uttarakhand and 1348 kg per hectare in Tamil Nadu. The acreage of minor millet cultivation in India has substantially reduced, coming down from 2,447 thousand hectares in the 1990-91 season to a mere 458 thousand hectares during 2019-20. The main reason behind this phenomenon is due to the excessive cultivation of major cereal crops (APEDA, 2024).

Fertilization is required for enhancing the quantity and quality of crop yield (Pathak *et al.*, 2012; Dhaka *et al.*, 2023a). Minor millets' productivity is significantly constrained by the poor utilization of major nutrients, particularly nitrogen (N) and phosphorus (P), which are imperative for plant development and growth. Nitrogen plays a vital role in photosynthesis and general growth of plants, while phosphorus plays a vital role in the growth of roots, energy transmission, and plant establishment at early stages (CGIAR, 2005). The yield of minor millets is relatively low, unable to meet consumer needs, mainly because of production by economically poor farmers working under inferior conditions. The use of low-yielding local varieties, as well as the inability to apply better agronomic practices, adds to the problem of realizing low yields (Triveni *et al.*, 2019). The optimal and balanced use of fertilizers, especially nitrogen and phosphorus, is essential to increase the yield of minor millets. The timely and wise use of major nutrients helps in increased crop yields and allows farmers to gain more profit. So, considering the above facts the present research entitled "Effect of different fertility levels on yield and economics of minor millets" was conducted at Agronomy Research Farm of CCS Haryana Agricultural University, Hisar to study the yield and economic performance of minor millets.

Materials and Methods

Experimental site and location

The trial was conducted in the *kharif* season of 2023 at Agronomy Research Farm of CCS Haryana Agricultural University, Hisar. Hisar has a latitude of 29°10' N and longitude of 75°46' E, and the altitude is 215 meters above mean sea level. The experimental field exhibited a sandy soil type, which was slightly alkaline in nature with a pH of 7.8 as measured. The organic carbon content recorded was 0.51%, and the available nitrogen content was recorded at 147 kg ha^{-1}, representing a low level. Phosphorus levels were recorded at 18.2 kg ha^{-1}, representing a medium level, and potassium levels were recorded at 280 kg ha^{-1}, also representing a medium status.

Experiment employed a split plot concept, with three replications and sixteen treatment combinations. The work involves four levels of various minor millets, namely Foxtail millet (SIA3156), Barnyard millet (VL207), Proso millet (TNAU202), and Finger millet (GPU67), which are taken as main plots. In addition, four levels of nitrogen and phosphorus are applied in sub-plots, which are identified as $N_0 + P_0$, $N_{20} + P_{10}$, $N_{40} + P_{20}$, and $N_{60} + P_{30}$ kg ha^{-1}. Land preparation involved two ploughing operations using a harrow and a cultivator. This was followed by planking and pre-sowing irrigation to provide adequate moisture levels. During the preparation in the field stage, the lauout procedure was conducted with the help of levelling rods. It involved the entire application of phosphorus and half of the dosage of nitrogen, as per treatments prescribed. Sowing was done at a row width of 30 cm in mid-June. The residual nitrogen was top dressed after the thinning and gap filling stages. Urea and Di-ammonium Phosphate (DAP) served as the phosphorus and nitrogen sources. Weeding was done manually at 20-25 and 35-40 DAS. Two irrigations were applied as per crop needs during dry weather conditions. Harvesting was done manually, later followed by sun drying in the field for 4 to 5 days. Subsequent to this, threshing was done plot by plot.

Observations Recorded

The data gathered included yield traits such as No. of effective tillers (mrl^{-1}), Number of grains ear head^{-1}, Test weight (g), Grain yield (kg ha^{-1}), Stover yield (kg ha^{-1}), Biological yield (kg ha^{-1}) and Harvest Index (%). The effective tillers were counted from a row length of one meter using a measuring rod. Also, randomly selected ear heads from each plot were counted, and the number of grains per ear head was noted. The test weight, that is, 1000 grains weight (g) per sample, was manually counted, and the equivalent weight was noted using a weighing balance in the laboratory. Grain and biological yield per plot was noted and then converted to kilograms per hectare (kg ha^{-1}). Stover yield per plot was obtained by subtracting grain weight from biological yield from individual plot produce. Harvest index was obtained by dividing the grain yield by the biological yield and then multiplying the obtained value by one hundred. Economic analysis per treatment was obtained by calculating the gross return and net return both in terms of ^{1} per hectare. The B:C (Benefit: Cost) ratio was calculated by dividing the gross returns by the cost of cultivation. The collected data were analyzed using the analysis of variance (ANOVA) technique as outlined by Gomez and Gomez (1984) under the context of a split plot design. A least significance test was used to analyze the treatment effects at a 5% level of significance.

Results and Discussion

Effect of different fertility levels on yield parameters

The data on yield traits are presented in Table 1 and 2. The data on the effect of nitrogen and phosphorus levels on all the yield attributes of minor millets were found to be significantly effective. The highest number of effective tillers (39.53 mrl^{-1}) were observed in foxtail millet, which were significantly higher as compare to barnyard (33.97 mrl^{-1}) and finger millet (30.22 mrl^{-1}) but statistically at par with proso millet (35.58 mrl^{-1}). However, lowest number of effective tillers mrl^{-1} was found in finger millet (30.22 mrl^{-1}). Similarly, higher number of grains $earhead^{-1}$ was found in foxtail millet (1953) which was significantly higher as compare to barnyard millet (1706), finger millet (1546) and proso millet (986). Apparently, the longest ear head length was observed in proso millet (30.00 cm), followed by foxtail millet (22.25 cm). In contrast, the shortest ear head length was recorded in finger millet (8.92 cm). Similarly, Proso millet had significantly higher grain weight (4.40 g) as compare to other minor millets under study. Whereas, lowest 1000 grain weight was found in foxtail millet (2.41 g). The significant difference was observed in the grain, straw, biological yield and harvest index across different minor millets. The significantly higher grain yield was recorded in foxtail millet (1917 kg ha^{-1}) as compare to barnyard millet (1624 kg ha^{-1}). However, the grain yield recorded in barnyard, proso (1574 kg ha^{-1}) and finger millet (1483 kg ha^{-1}) were found non- significant to each other. But higher straw yield was recorded in barnyard millet (4041 kg ha^{-1}), which was significantly higher over foxtail and proso millet but statistically at par with finger millet (3866 kg ha^{-1}). The lowest straw yield was found in proso millet (3463 kg ha^{-1}). Similarly, highest biological yield was achieved by barnyard millet (5665 kg ha^{-1}), followed by foxtail millet (5516 kg ha^{-1}). Conversely, the lowest biological yield was recorded in proso millet (5038 kg ha^{-1}). However, Maximum harvest index was recorded in foxtail millet (34.34), which was significantly at par with proso millet (30.53) but significantly higher than barnyard millet (28.27) and finger millet (27.19). The differences observed can be explained by genetic characteristics, growth habits, and resource partitioning strategies. In particular, foxtail millet focuses on grain yield, while barnyard millet focuses on total biomass development. Similar findings were reported by Soutade and Raundal (2022) in various little millet varieties.

In case of different nitrogen and phosphorus levels, significant effect was found on different yield attributes and yield. For nutrient response, the highest number of effective tillers (41.14 mrl^{-1}) were recorded in T_4 (60:30 kg NP ha^{-1}). However, it was found to be statistically at par with T_3 (39.11 mrl^{-1}). The lowest value for number of effective tillers were recorded for T_1 (25.69 mrl^{-1}). Similarly, the longest ear head length was observed in T_4 (22.58 cm) but statistically at par with T_3 (21.75 cm). In contrast, the shortest ear head length was recorded in T_1 (13.75 cm). The number of grains ear $head^{-1}$ was also significantly influenced by various nitrogen and phosphorus fertility levels. The treatment T_4 having 60:30 kg NP ha^{-1} (1851) gave significantly higher number of grains $earhead^{-1}$ which was statistically similar to treatment T_3 having 40:20 kg NP ha^{-1} (1775). However, the treatment T_1 (control) recorded minimum number of grains ear $head^{-1}$ (1056). Also, treatment T_4 (60:30 kg NP ha^{-1}) revealed higher 1000 grain weight (3.51 g) in comparison to T_2 (20:10 kg NP ha^{-1}) and T_1 (control) but statistically similar to treatment T_3 (3.46 g). The minimum 1000 grain weight (2.60 g) was also recorded in treatment T_1. The grain yield (kg ha^{-1}) was also significantly affected by nitrogen and phosphorus levels. The treatment with T_4 (60: 30 kg NP ha^{-1}) resulted in the significantly higher grain yield (2063 kg ha^{-1}) over treatment T_2 (20:10 kg NP ha^{-1})) and T_1 (control), but statistically similar to the treatment with T_3 (1952 kg ha^{-1}). On the conversely, lowest grain yield (992 kg ha^{-1}) was recorded in treatment T_1 (control). Similarly, highest straw yield was observed in the treatment with 60:30 kg NP ha^{-1} (4146 kg ha^{-1}), which was significantly similar from the treatment with 40:20 kg NP ha^{-1} (4056 kg ha^{-1}) but significantly higher over T_2 (20:10 kg NP ha^{-1}) and T_1 (control). The lowest straw production (3088 kg ha^{-1}) was also recorded in treatment T_1 (control). Treatment T_4 also produced highest biological yield (6209

Table 1: Effect of different fertility levels on yield attributes of minor millets.

Treatment	NET	EL	NGE	TW
	Yield attributes			
Minor millets				
Foxtail millet (SIA 3156)	39.53	21.33	1953	2.41
Barnyard millet (VC 207)	33.97	16.75	1706	3
Proso millet (TNAU 202)	35.58	30	986	4.4
Finger millet (GPU 67)	30.22	8.92	1546	2.92
SE(m) ±	1.18	0.65	54.66	0.04
CD at 5%	**4.15**	**2.16**	**193**	**0.15**
Fertility levels (kg ha^{-1})				
T1 – Control	25.69	13.75	1056	2.6
T2 - N20P10	34.36	18.92	1508	3.15
T3 - N40P20	39.11	21.75	1775	3.46
T4 - N60P30	41.14	22.58	1851	3.51
SE(m) ±	1.66	0.49	46.59	0.03
CD at 5%	**4.86**	**1.43**	**137**	**0.1**

NET: No. of effective tillers (mrl^{-1}); EL: Earhead length (cm); NGE: No. of grain $earhead^{-2}$; TW: Test weight (g)

Table 2: Effect of different fertility levels on yield of minor millets.

Treatment	GY	SY	BY	HI
Yield				
Minor millets				
Foxtail millet (SIA 3156)	1917	3599	5516	34.34
Barnyard millet (VC 207)	1624	4041	5665	28.27
Proso millet (TNAU 202)	1574	3463	5038	30.53
Finger millet (GPU 67)	1483	3866	5349	27.19
SE(m) ±	62	100	110	1.11
CD at 5%	**220**	**352**	**388**	**3.92**
Fertility levels (kg ha^{-1})				
T1 – Control	992	3088	4080	24.41
T2 - N20P10	1601	3668	5269	30.45
T3 - N40P20	1952	4056	6008	32.29
T4 - N60P30	2063	4146	6209	33.18
SE(m) ±	42	79	80	0.86
CD at 5%	**124**	**231**	**234**	**2.54**

GY: Grain yield (kg ha^{-1}); SY: Straw yield (kg ha^{-1}); BY: Biological yield (kg ha^{-1}); HI: Harvest Index (%)

kg ha^{-1}), which was found statistically similar to T_3 (6008 kg ha^{-1}). The lowest biological yield was also observed in treatment T_1 (4080 kg ha^{-1}). Furthermore, maximum harvest index was found treatment T_4 (33.18), which was found statistically at par with T_3 (32.29) but significantly higher as compare to T_2 (20: 10 kg ha^{-1}) and T_1 (control). Also, the lowest harvest index was recorded in treatment T_1 (24.41). Use of this balanced fertilizer increased physiological processes, enhanced the efficiency of nutrient utilization, and maintained a healthy source-sink. This led to a greater number of effective tillers, grains per earhead, earhead length, and 1000-grain weight in comparison to decreased levels of nutrients. The low levels of nutrients in the control most probably accelerated senescence by reducing leaf area index, dry matter production, and chlorophyll content. This photochemical impairment ultimately led to reduced grain and straw yield. The results concur with the findings of Dhaka *et al.*, (2025), Roy *et al.*, (2002), Mahajan *et al.*, (2017), Deshmukh (2007), and Nigade *et al.*, (2014).

Effect of different fertility levels on economics of cultivation of minor millets

Among different minor millets (Table 3), maximum cost of cultivation (Rs. 37831 ha^{-1}) was recorded with finger millet, whereas maximum gross returns (Rs. 59517 ha^{-1}), net returns (Rs. 27486 ha^{-1}) and B C ratio (1.84) was recorded with foxtail millet. However, the minimum cost of cultivation (Rs. 30244 ha^{-1}), gross returns (Rs. 39962 ha^{-1}), net returns (Rs. 9717 ha^{-1}) and B C ratio (1.30) was recorded with proso millet. This is likely because foxtail millet had maximum productivity

Table 3: Effect of different fertility levels on economics minor millets.

Treatment	CC	GR	NR	BC
Economics				
Minor millets				
Foxtail millet (SIA 3156)	32031	59517	27486	1.84
Barnyard millet (VC 207)	32282	49224	16942	1.51
Proso millet (TNAU 202)	30244	39962	9717	1.3
Finger millet (GPU 67)	37831	56803	18972	1.48
Fertility levels (kg ha^{-1})				
T1 – Control	29676	32415	2739	1.09
T2 - N20P10	32071	49994	17922	1.56
T3 - N40P20	34239	59877	25637	1.75
T4 - N60P30	36401	63220	26819	1.74

CC: Cost of cultivation (Rs.ha^{-1}); GR: Gross returns (Rs. ha^{-1}); NR: Net returns (Rs.ha^{-1}); BC: B:C ratio

compared to other millets and its cost of cultivation was lower than that of finger and barnyard millet. Additionally, market price of different millet, also influenced the gross returns of the crops.

However, among the various nitrogen and phosphorus levels, the highest cost of cultivation (Rs. 36401 ha^{-1}) was, gross returns (Rs. 63220 ha^{-1}) and net returns (Rs. 26819 ha^{-1}) were observed in treatment T_4 (60:30 kg NP ha^{-1}), followed by T_3. However, the highest BC ratio (1.75) found in T_3 (40:20 kg NP ha^{-1}) followed by T_4 (1.74). The prime objective of agricultural practices is to maximize the return on every rupee spent, which serves as the prime measuring stick for gauging the implementation and performance of these practices. This also highlights the optimal amount of inputs that can be utilized to achieve better financial outcomes. The results are consistent with previous research work carried out by Dhaka *et al.*, (2025a), Radha *et al.*, (2019), Patil *et al.*, (2015), and Shukla *et al.*, (2023).

Conclusion

The study concluded that among the tested minor millets, foxtail millet (SIA 3156) exhibited better performance in terms of yield attributes, productivity, and economic returns. The results showed that it had the maximum number of effective tillers, grain yield, and net returns with a benefit-cost (B:C) ratio of 1.84, hence tagging it as the most economically sound millet choice. Proso millet had the maximum test weight and earhead length but its relatively lower grain yield and net returns reduced its overall profitability. Management of nutrients significantly influenced all the parameters assessed. The application of 60:30 kg NP ha^{-1} (T_4) produced the highest grain yield, biological yield and net returns. The results underscore the importance of effective nutrient application for improving millet productivity and profitability.

Thus, foxtail millet, in combination with a fertility regime of 60:30 kg NP ha^{-1}, is suggested as the ideal and sustainable option for yield and economic return augmentation for minor millet cultivation in semiarid regions of Haryana.

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