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Effect of planting geometry and NPK levels on yield, nutrient uptake and economics of transplantedbarnyard millet

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Abstract
Field experiment was conducted during October, 2020 – January, 2021 at a farmer's field of Paranjervazhi village, Kangeyam Taluk, Tiruppur District, Tamilnadu, India to study the effect of planting geometry and NPK levels on yield, nutrient uptake and economics of transplanted barnyard millet. The experiment was laid out in randomized block design with factorial arrangements (FRBD) and replicated thrice. The treatment includes five planting geometry (25 × 10 cm (Recommended line sowing), 15 × 10 cm, 20 × 10 cm, 15 × 15 cm and 20 × 20 cm) and four NPK levels (75 % recommended dose of fertilizer (RDF) (30:22.5:37.5 kg NPK ha^{-1}), 100 % RDF (40:30:50 kg NPK ha^{-1}), 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}) and 150 % RDF (60:45:75 kg NPK ha^{-1})). Among the planting geometry, 15 × 15 cm recorded higher yields (grain: 2792 kg ha^{-1} and straw: 7805 kg ha^{-1}) and nutrient uptake of transplanted barnyard millet. This was followed by 20 × 20 cm which was on par with 20 × 10 cm. With regards to NPK levels, application of 150 % RDF (60:45:75 kg NPK ha^{-1}) recorded higher yields (grain: 2830 kg ha^{-1} and straw: 7899 kg ha^{-1}) and nutrient uptake of transplanted barnyard millet which is on par with 125% RDF (50:37.5:62.5 kg NPK ha^{-1}). Among the treatment combinations, seedlings transplanted at 15 × 15 cm and fertilized with150% RDF (60:45:75 kg NPK ha^{-1}) registered higher values for yields and nutrient uptake of transplanted barnyard millet which was on par with seedling planted at 15 x 15 cm and fertilized with 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}). In economic point of view, seedlings transplanted at 15 × 15 cm and fertilized with 125% RDF (50:37.5:62.5 kg NPK ha^{-1}) recorded higher net return and return rupee^{-1} invested in transplanted barnyard millet. Therefore, it can be concluded that transplanting of seedlings at 15 × 15 cm and fertilized with 125 % RDF - 50:37.5:62.5 kg NPK ha^{-1} holds immense potentiality to uplift the productivity, uptake of nutrients and profitability of transplanted barnyard millet.

Keywords: barnyard millet, planting geometry, npk levels, yield, nutrient uptake, economics

Introduction

Millets exhibit unique characteristics amongst cereals, which are small seeded grasses that are hardy and grow well in dry zones as rainfed crops under marginal conditions of soil fertility and moisture. Under the changing scenario of global warming and climate change, cultivation of ecologically sound and hardy millets may be a wise alternative for optimum output with food and nutritional security (Wang *et al*., 2018) [28]. Barnyard millet is one of the fastest growing crops and it is also known for their fast maturity, high storability and the ability to grow on poor soils (Yabuno, 1987) [29]. Globally, India is the biggest producer of barnyard millet, both in terms of area (1.46 lakh ha^{-1}) and production (1.47 lakh tonnes) with an average productivity of 1034 kg ha^{-1} (IIMR, 2018) [7]. In India, it is mainly cultivated in Odisha, Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu and Bihar besides hills of Uttar Pradesh. Barnyard millet cultivation is dominant in dry lands and hill areas by tribal farmers in Ramanathapuram, Madurai, Virudhunagar, Theni, Salem, Namakkal, Dharmapuri, Krishnagiri, Villupuram, Dindigul, Coimbatore and Erode districts of Tamil Nadu (Senthil *et al*., 2015) [22]. Nowadays the demand for barnyard millet has risen drastically due to its nutritional quality and high dietary fibre; it helps in preventing diabetes and cardiovascular disease with regular intake. Barnyard millet is grown in diverse soil, varying rainfall regimes and in area widely differing in thermo and photoperiods. It is reportedly known for its high degree of tolerance against drought, salinity and water logging conditions. All these features make barnyard millet an ideal supplementary crop for subsistence farmers and as an alternate crop during the failure of monsoons in rice/major crop cultivating areas (Gupta *et al*., 2009) [6]. But the productivity of barnyard millet is low. Because, (i) Barnyard millet is mostly grown in rainfed and hilly areas on poor shallow and marginal soils. (ii) Seeds are often broadcasted and it is cultivated under unfertilized and unweeded condition. Therefore, a suitable sowing / planting method, balanced supply of nutrients and proper weed management practices are essential for obtaining higher yield. Among them, suitable planting method and fertility management are greatly influenced on the productivity of Barnyard millet. Planting geometry is an important factor to achieve higher production by better utilization of resources and in turn higher production of photosynthates. The ideal plant geometry can assure healthy and uniform stand in the main field and ensure higher productivity. When the plant density exceeds an optimum level, competition among plants for light above ground and nutrients below ground becomes severe (Bayala *et al.*, 2002) [2]. It is therefore necessary to optimize the density of plants per unit area under appropriate spacing to obtain maximum yield. It is also necessary to address the importance of plant density with respect to soil fertility.

Nutrient management is a key issue in achieving higher biomass of any crop plant and maintaining soil fertility. Nitrogen, phosphorus and potassium are the primary macro nutrients mainly responsible for productivity of crops. Nitrogen is a vital plant nutrient and a major yield determining factor required for production of growth. It is essential for carbohydrates metabolism within plants and stimulates vegetative and along with development uptake of other nutrients (Khan *et al*., 2014) [8]. Phosphorus plays an important part in many physiological processes occur within a developing and maturing stages of plant. It is also involved in enzymatic reaction and essential for cell division. An adequate amount of phosphorus is necessary for earlier maturity, rapid growth and improve the quality of vegetative growth (Onasanya *et al*., 2009) [13]. Potassium plays a significant role in biochemical functions of the plant like activating various enzymes, improvement of protein, carbohydrates and fat concentration, developing tolerance against drought and resistance to frost, lodging, pests and disease attack (Marschner, 1995) [12]. Keeping the above facts in consideration, the present experiment was programmed to study the effect of planting geometry and NPK levels on productivity, nutrient uptake and economics of Barnyard millet under transplanted condition.

Materials and Methods

Field experiment was conducted during samba season (October, 2020 – January, 2021) at a farmer's field of Paranjervazhi village, Kangeyam Taluk of Tiruppur District, Tamilnadu, India to study the effect of planting geometry and NPK levels on yield, nutrient uptake and economics of transplanted barnyard millet. The soil of the experimental field is sandy clay loam with an organic matter content of 0.30 % and pH of 7.9. The available N, P and K were 245.21, 17.29, 382.85 kg ha^{-1} respectively. The experiment was laid out in Randomized Block Design with Factorial arrangements (FRBD) and replicated thrice. The treatment includes two factors, five planting geometry [25 × 10 cm (Recommended line sowing), 15 × 10 cm, 20 × 10 cm, 15 × 15 cm and 20 × 20 cm] and four NPK levels [75 % Recommended Dose of Fertilizer (RDF) (30:22.5:37.5 kg NPK ha^{-1}), 100 % RDF (40:30:50 kg^{-1}), 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}) and 150 % RDF (60:45:75 kg NPK ha^{-1})]. The entire dose of P_2O_5 was applied as basal. N and K were applied in three equal splits at basal, tillering and flowering. Barnyard millet variety Co (KV) 2 was used for this study. The grain yield (@ 14 % moisture) and straw yield of barnyard millet was recorded from the net plot area and expressed in kg ha^{-1}. The plant samples used for dry matter estimation were ground into fine powder and used for chemical analysis to estimate the uptake of major nutrients at harvesting stage. The cost of inputs, labour charges and prevailing market rate of farm produce were taken into consideration for working out gross and net income per hectare. The return rupee^{-1} invested was worked out for various treatments by dividing the gross income by cost of cultivation. The data on various characters studied during the investigation were statistically analyzed as suggested by Gomez and Gomez (1984).

Results and Discussion

Planting geometry and NPK levels significantly influenced the yields, nutrient uptake and economics of transplanted Barnyard millet (Table 1 and Table 2).

Yield

Planting geometry and NPK levels significantly enhanced the yield of transplanted barnyard millet (Table 1). Among the different planting geometry, adoption of spacing 15 × 15 cm recorded remarkably higher grain and straw yield of 2792 kg ha^{-1} and 7805 kg ha^{-1}, respectively. This might be due to enhanced stature of yield attributes, thus forming larger sink size coupled with efficient translocation of photosynthates to sink was noticed under optimum planting pattern with transplanting of medium aged seedlings. Optimum planting pattern is the prerequisite for proper utilization of growth resources and ultimately to exploit the potential productivity of the crop (Kumar *et al.*, 2019) [10].

Table 1: Effect of planting geometry and NPK levels on Yield and Nutrient uptake of barnyard millet during samba season 2020-2021

Treatment	Yield (kg ha^{-1})		Nutrient uptake (kg ha^{-1})		
	Grain	Straw	Nitrogen	Phosphorus	Potassium
Factor A – Planting Geometry(S)					
S_1	2361	7273	42.13	12.63	70.73
S_2	2517	7508	52.08	15.00	73.47
S_3	2627	7637	55.05	17.18	75.12
S_4	2792	7805	58.79	19.08	77.37
S_5	2684	7694	56.00	17.40	75.82
S. Ed.	42.29	47.26	0.57	0.16	0.69
CD (P = 0.05)	85	95	1.15	0.33	1.38
Factor B – NPK levels (F)					
F_1	2310	7160	39.84	12.22	69.89
F_2	2476	7435	49.22	16.21	72.13
F_3	2763	7843	60.80	23.54	77.42
F_4	2830	7895	61.58	23.85	78.56
S. Ed.	54.73	61.19	0.45	0.14	0.60
CD (P = 0.05)	110	123	0.90	0.29	1.23
Interaction - S × F					
S_1F_1	2183	7014	36.48	10.91	69.19
S_1F_2	2397	7304	42.51	13.06	70.84
S_1F_3	2422	7383	44.45	13.24	71.02
S_1F_4	2443	7392	45.07	13.32	71.87
S_2F_1	2249	7129	38.73	11.98	69.51
S_2F_2	2450	7403	49.64	14.81	72.06
S_2F_3	2650	7744	59.87	16.58	75.65
S_2F_4	2717	7757	60.09	16.64	76.64
S_3F_1	2347	7180	40.16	12.63	69.80
S_3F_2	2461	7445	50.40	15.43	72.40
S_3F_3	2796	7930	64.43	20.08	78.61
S_3F_4	2903	7992	65.20	20.57	79.66
S_4F_1	2379	7229	41.80	12.72	70.25
S_4F_2	2547	7558	52.22	16.21	72.82
S_4F_3	3078	8172	70.28	23.54	82.41
S_4F_4	3133	8260	70.85	23.85	84.01
S_5F_1	2390	7247	42.01	12.87	70.68
S_5F_2	2523	7463	51.22	15.52	72.55
S_5F_3	2871	7988	64.96	20.41	79.42
S_5F_4	2953	8076	65.71	20.80	80.62
S. Ed.	83.58	88.56	1.0	0.31	1.37
CD (P = 0.05)	168	178	2.01	0.62	2.76

This was followed by 20 × 20 cm and recorded grain and straw yield of 2684 kg ha^{-1}and 7694 kg ha^{-1}. This was on par with 20 × 10 cm with a grain and straw yield of 2627 kg ha^{-1} and 7637 kg ha^{-1}. The lesser grain (2361 kg ha$^{-1)}$ and straw yield (7273 kg ha^{-1}) were recorded under 25 × 10 cm due to lesser productive tillers hill^{-1}. These results are in line with the findings of Rashid *et al*. (2009). With regards to various

NPK levels, 150 % RDF (60:45:75 kg NPK ha^{-1}) recorded higher grain and straw yield of 2830 kg ha^{-1} and 7899 kg ha^{-1}, respectively which was on par with 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}) and registered the grain and straw yield of 2763 kg ha^{-1} and7843 kg ha^{-1}.This might be due to greater availability of nutrients and metabolites for growth and development which leads to higher productivity of individual plants (Reddy *et al*., 2020). These results are in conformity with the findings of Paul *et al*. (2016). The lesser grain and straw yield of 2310 kg ha^{-1} and 7160 kg ha^{-1} were noticed under 75 % RDF – 30:22.5:37.5 kg NPK ha^{-1}. This could be due to lesser availability of nutrients which leads to increased competition for resources resulted in lesser yield (Vimalan *et al*., 2019b). These results are in accordance with the findings of Korir *et al*. (2018).

Among the interaction effect, seedlings transplanted at 15 × 15 cm and fertilized with 150 % RDF (60:45:75 kg NPK ha^{-1}) recorded higher grain and straw yield of 3133 kg ha^{-1} and 8260 kg ha^{-1}, which was on par with seedlings planted at 15 × 15 cm and fertilized with 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}). Wider spacing and adequate supply of plant nutrients helps in better photosynthesis and growth of millet which helps in higher yield. These results are in accordance with the findings of Prakasha *et al*. (2018) [15]. Due to better availability of NPK to plants resulted in higher photosynthetic activity and accumulation of photosynthates in sink resulted in more number of filled grains and higher yields. These results are in agreement with those obtained by Rurinda *et al.* (2014) [21] and Vimalan *et al.* (2019a). The lesser grain and straw yield of 2183 kg ha^{-1} and 7014 kg ha^{-1} was recorded under seedlings planted at 25 × 10 cm and fertilized with 75 % RDF - 30:22.5:37.5 kg NPK ha^{-1}. Narrow spacing and inadequate supply of nutrients leads to less chlorophyll synthesis and dehydrogenase activity, also affects source to sink relationship which reflects in lesser yield (Rajesh, 2011). This result was in accordance with the findings of Raundal *et al.* (2017).

Nutrient Uptake

Planting geometry and NPK levels have exerted significant influence on the N, P and K uptake of barnyard millet under transplanted condition (Table 1). Among the different planting geometry, the higher nutrient uptake by the crop was recorded in 15 × 15 cm. This could be due to the impact of favourable environment and less competition among plants by optimum spacing and moderate age of seedling that assured better crop establishment. These results are in conformity with the findings of Avasthe *et al.* (2011) and Kumar *et al*. (2019) [10]. The lesser nutrient uptake was observed under 25 × 10 cm (Recommended line sowing) due to increased plant population per unit area results in increased competition for resources which leads to lesser nutrient uptake by crops (Rajesh, 2011). The result was in conformity with the findings of Sri Devi and Chellamuthu (2012) [24].

With respect to NPK levels, 150 % RDF - 60:45:75 kg NPK ha^{-1} registered higher nutrient uptake by barnyard millet and it was on par with 125 % RDF - 50:37.5:62.5 NPK ha^{-1}. It is well emphasized that increasing rate of NPK markedly improved overall growth of the crop in terms of dry matter production per plant by virtue of its impact on morphological and photosynthetic components along with accumulation of nutrients (Singh *et al*., 1997 and Camara *et al.*, 2003). The highest nutrient uptake might be due to better nutritional environment, which influenced the crop growth rate and dry matter production. Similar findings were observed by Vimalan *et al*. (2019b). Barnyard millet fertilized with 75 % RDF – 30:22.5:37.5 kg NPK ha^{-1} recorded lesser nutrient uptake than other NPK levels.

Table 2: Effect of planting geometry and NPK levels on Economics of barnyard millet during samba season 2020-2021

Treatment details	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1}))	Return rupee^{-1} invested
S_1F_1	32712.83	72504.00	39791.17	2.22
S_1F_2	33585.77	79214.00	45628.23	2.36
S_1F_3	34343.17	80043.00	45699.83	2.33
S_1F_4	35180.18	80682.00	45501.82	2.29
S_2F_1	36551.84	74599.00	38047.16	2.04
S_2F_2	37424.78	80903.00	43478.22	2.16
S_2F_3	38182.17	87244.00	49061.83	2.28
S_2F_4	39019.19	89267.00	50247.81	2.29
S_3F_1	36457.91	77590.00	41132.09	2.13
S_3F_2	37330.85	81275.00	43944.15	2.18
S_3F_3	38088.25	91810.00	53721.75	2.41
S_3F_4	38925.26	95082.00	56156.74	2.44
S_4F_1	36429.63	78599.00	42169.37	2.16
S_4F_2	37302.57	83968.00	46665.43	2.25
S_4F_3	38109.97	100512.00	62402.03	2.64
S_4F_4	38896.98	102250.00	63353.02	2.62
S_5F_1	36316.51	78947.00	42630.49	2.17
S_5F_2	37189.45	83153.00	45963.55	2.24
S_5F_3	37946.85	94118.00	56171.15	2.48
S_5F_4	38783.86	96686.00	57902.14	2.49

The interaction effect between planting geometry and NPK levels was found to be significant. Transplanting of seedlings at 15 × 15 cm and fertilized with 150 % recommended dose of fertilizers 60:45:75 kg NPK ha^{-1} recorded significantly higher nutrient uptake, which was on par with seedlings planted at 15 × 15 cm and fertilized with 125 % RDF – 50:37.5:62.5 kg NPK ha^{-1}. The highest level of NPK resulted in the maximum uptake of nitrogen probably due to close inter-relationship between N and P metabolism in the plant cell. Similar inferences were reported by Machado *et al.* (1985). A well developed and healthy root system played an important role in uptake and translocation of nutrients from the soil particularly with wider spacing and increased application of NPK. The result was in conformity with the findings of Roy *et al*. (2001). Seedlings planted at 25 × 10 cm and fertilized with 75 % RDF – 30:22.5:37.5 kg NPK ha^{-1} recorded lesser nutrient uptake. This might be due to lesser availability of nutrients and increased plant population which results in increased competition for resources. The present result was in accordance with the results obtained by Kumar *et al*. (2019) [10] and Vimalan *et al*. (2019b) [26, 27].

Economics

The ultimate aim of any agricultural technology/practice is to realize maximum returns per rupee invested. This also gives a clear idea about the optimum level of inputs that could be used to obtain higher net profit. The net return and return rupee^{-1} invested of transplanted barnyard millet was greatly influenced by different planting geometry and NPK levels (Table 2). The treatment combination, S_4F_3 (15 × 15 cm + 125 % RDF - 50:37.5:62.5 kg NPK ha^{-1}) registered higher net return of Rs. 62402.03 and return rupee^{-1} invested of Rs.2.64 in transplanted barnyard millet. This might be due to optimum plant population maintained in a unit area and increased level of fertilizer application leads to higher grain yield resulted in higher net return and return rupee^{-1} invested resulted in more profit. This was followed by S_4F_4 (15 × 15 cm + 150 % RDF - 60:45:75 kg NPK ha^{-1}) which recorded a net return of Rs. 63353.02 and return rupee^{-1} invested of Rs.2.62. The least net return and return rupee^{-1} invested of Rs. 38047.16 and Rs.2.04 was observed under S_2F_1 (15 × 10 cm + 75 % RDF – 30:22.5:37.5 kg NPK ha^{-1}) due to lesser grain and straw yield. These results are in line with the earlier findings of Sunitha *et al.* (2004) [25] and Bhomte *et al*. (2013) [3].

Conclusion

The experimental results enlightened that there was noticeable variation on the productivity of transplanted barnyard millet due to adoption of different planting geometry and NPK levels. Planting of seedlings at 15 × 15 cm and fertilized with 150 % RDF – 60:45:75 kg NPK ha^{-1} (S_4F_4) registered more productivity and higher nutrient uptake in transplanted barnyard millet. However, the treatment combination S_4F_3 (15 × 15 cm + 125 % RDF – 50:37.5:62.5 kg NPK ha^{-1}) almost narrow S_4F_4 in terms of returns per rupee invested and it was economically viable practice. Therefore, it can be concluded that transplanting of seedlings at 15 × 15 cm and fertilized with 125 % RDF - 50:37.5:62.5 kg NPK ha^{-1} holds immense potentiality to uplift the productivity, enhance the uptake of nutrients and to boost the profitability of transplanted barnyard millet.

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