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Effect of planting geometry and NPK levels on growth and yield of transplanted barnyard 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 growth and yield 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 growth (plant height, number of tillers $hill^{-1}$, leaf area index, dry matter production), yield attributes (number of earheads $hill^{-1}$, length of earhead, number of grains per earhead, weight of earhead, test weight) and yields (grain: 2792 kg ha^{-1} and straw: 7805 kg ha^{-1}) of transplanted barnyard millet. With regards to NPK levels, application of 150 % RDF (60:45:75 kg NPK ha^{-1}) recorded higher growth (plant height, number of tillers $hill^{-1}$, leaf area index, dry matter production), yield attributes (number of earheads $hill^{-1}$, length of earhead, number of grains per earhead, weight of earhead, test weight) and yields (grain: 2830 kg ha^{-1} and straw: 7899 kg ha^{-1}) of transplanted barnyard millet which was on par with 125 % RDF (50:37.5:62.5kg NPK ha^{-1}). Among the treatment combinations, seedlings transplanted at 15 × 15 cm and fertilized with 150 % RDF (60:45:75 kg NPK ha^{-1}) registered its superiority over others and recorded higher values for growth and yield of transplanted barnyard millet which was on par with seedling transplanted at 15 ×15 cm and fertilized with 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}). 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 of transplanted barnyard millet.

Keywords: barnyard millet, planting geometry, NPK levels, growth, yield

Introduction

Millets are one of the oldest foods known to humans and possibly the first cereal grain to be used for domestic purposes. Millets are small-seeded grasses that are hardy and grow well in dry zones as rainfed crops under marginal conditions of soil fertility and moisture. Barnyard millet is one of the fastest growing crops among all millets and it is also known for their fast maturity, high storability and the ability to grow on poor soils (Yabuno, 1987) [33]. In India it is mainly cultivated in Odisha, Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu and Bihar besides hills of Uttar Pradesh. In Tamilnadu, minor millets occupy an area of 0.21 lakh ha with a production of 0.25 lakh tonnes and the average productivity is 1150 kg ha^{-1} (Anonymous, 2020) [1]. Now days 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. 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. Plant spacing plays an important role on growth, development and yield of millet crops. Optimum plant density ensures plants to grow properly making better utilization of sunlight and soil nutrients (Miah *et al*., 1990). Nitrogen is a vital plant nutrient and a major yield determining factor required for production of growth. Itis essential for carbohydrates metabolism within plants and stimulates vegetative and along with development uptake of other nutrients (Khan *et al.*, 2014) [15]. 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 improves the quality of vegetative growth (Onasanya *et al*., 2009) [22]. 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) [20]. As far as Barnyard millet is concerned a very few works has been reported on planting geometry and NPK levels on productivity of barnyard millet particularly nil under transplanted condition. Considering the above facts, this experiment was programmed to study the effect of planting geometry and NPK levels on growth and yield of transplanted Barnyard millet.

Materials and Methods

Field experiment was conducted at farmer's field of Paranjervazhi village, Kangeyam Taluk, Tiruppur District, Tamil Nadu, India during October, 2020 – January, 2021 to study the effect of planting geometry and NPK levels on growth and yield of transplanted barnyard millet. The soil of the experimental field was 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 x 10 cm (Recommended line sowing), 15 x 10 cm, 20 x 10 cm, 15 x 15 cm and 20 x 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})]. 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 data on various characters studied during the investigation were statistically analyzed as suggested by Gomez and Gomez (1984) [10].

Results and Discussion

Planting geometry and NPK levels substantially influenced on growth and yield of transplanted Barnyard millet (Table 1 and Table 2).

Growth Attributes

Planting geometry and NPK levels significantly enhanced the growth attributes of transplanted barnyard millet (Table 1). Among the different planting geometry, adoption of 15 x 15 cm recorded remarkably higher values for plant height (189.77 cm), number of tillers hill-1 (7.66), leaf area index (16.64) and dry matter production (10925 kg ha-1) of transplanted barnyard millet. The growth parameters were increased as a result of effective utilization of water and nutrient and the tallest plant could be due to increase in cell division, elongation and expansion due to spacing. Optimum plant density results in increased number of tillers, LAI and increased the photosynthetic efficiency which induced to produce more DMP (Kalaraju *et al*., 2009) [13]. This was followed by 20 x 20 cm and recorded the plant height of 183.82 cm, number of tillers hill-1 of 7.45, leaf area index of 15.02 and dry matter production of 10713 kg ha-1. Direct seeded barnyard millet (25 x 10 cm) produced lesser growth attributes among the different planting geometry due to more competition between plants for resources.

With regards to NPK levels, 150 % RDF (60:45:75 kg NPK ha-1) recorded higher plant height (192.64 cm), number of tillers hill-1 (7.79), leaf area index (17.41) and dry matter production (11073 kg ha-1) of transplanted barnyard millet, which was on par with 125 % RDF (50:37.5:62.5 kg NPK ha-1) and the registered plant height of 190.29 cm, number of tillers hill-1 of 7.71, leaf area index of 17.13 and dry matter production of 10907 kg ha-1. The application of 125 and 150 per cent RDF provides sufficient nutrient to the plant which leads to anatomical changes such as increase in size of cells, inter cellular spaces, thinner cell walls and lower development of epidermal tissue resulted to increase in plant height and DMP which also results in increased number of tillers hill-1 due to luxuriant availability of nutrient for growth and development of auxiliary bud from which tillers are emerged. Similar findings were reported by Raundal *et al*. (2017) [28]. The application of 75 % RDF (30:22.5:37.5 kg NPK ha-1) recorded lesser growth attributes among the NPK levels due to lack of NPK to the plants. Among the interaction effect, seedlings transplanted at 15 x 15 cm and fertilized with 150 % RDF (60:45:75 kg NPK ha-1) recorded higher plant height (214.91 cm), number of tillers hill-1 (8.43), leaf area index (22.20) and dry matter production (11761 kg ha-1) of transplanted barnyard millet, which was on par with seedlings planted at 15 x 15 cm and fertilized with 125 % RDF.

Table 1: Effect of planting geometry and NPK levels on growth attributes of barnyard millet

Treatments	Plant height at harvest (cm)	No. of tillers hill^{-1}	LAI at flowering	DMP at harvest (kg ha^{-1})
Factor A – Planting Geometry (S)				
S_1	158.14	6.68	8.22	9893
S_2	170.37	7.14	12.15	10353
S_3	181.92	7.39	14.72	10580
S_4	189.77	7.66	16.64	10925
S_5	183.82	7.45	15.02	10713
S. Ed.	1.76	0.06	0.17	98.55
CD (P = 0.05)	3.54	0.13	0.34	198.08
Factor B – NPK levels (F)				
F_1	154.28	6.50	7.10	9750
F_2	170.00	7.05	11.75	10242
F_3	190.29	7.71	17.13	10907
F_4	192.64	7.79	17.41	11073
S. Ed.	1.58	0.05	0.15	88.14
CD (P = 0.05)	3.17	0.12	0.30	177.17
Interaction - S x F				
S_1F_1	138.37	6.42	6.38	9407
S_1F_2	163.98	6.62	8.30	10018
S_1F_3	164.78	6.82	9.04	10052
S_1F_4	165.41	6.86	9.16	10096
S_2F_1	146.48	6.46	6.47	9667
S_2F_2	170.01	6.95	10.11	10174
S_2F_3	182.15	7.53	15.97	10741

S_2F_4	182.85	7.63	16.05	10831
S_3F_1	161.99	6.50	7.13	9796
S_3F_2	171.01	7.15	12.67	10204
S_3F_3	196.41	7.90	19.29	11050
S_3F_4	198.28	8.00	19.79	11270
S_4F_1	160.77	6.54	7.72	9935
S_4F_2	172.81	7.29	14.63	10473
S_4F_3	210.57	8.36	22.00	11529
S_4F_4	214.91	8.43	22.20	11761
S_5F_1	163.78	6.60	7.81	9944
S_5F_2	172.18	7.22	13.06	10340
S_5F_3	197.55	7.96	19.35	11163
S_5F_4	201.75	8.03	19.85	11405
S. Ed.	3.52	0.13	0.33	197.09
CD (P = 0.05)	7.08	0.27	0.67	396.16

(50:37.5:62.5 kg NPK ha^{-1}) and registered the plant height of 210.57 cm, number of tillers hill^{-1} of 8.36, leaf area index of 22.00 and dry matter production of 11529 kg ha^{-1} in transplanted barnyard millet. This could be due to wider spacing with higher nutrient availability with less competition between plants for solar radiation, space and increased supply of nutrients and efficient utilization resulted in better growth compared to other fertilizer levels and spacing (Hanumantha Rao *et al*., 1982) [11]. These results are agreement with the findings of Muthukrishnan and Subramanian (1980) [21], and Chittapur *et al.* (1994) [6]. With enough roots and nutrients, tillers had the opportunity to grow to maturity and become fertile i.e., produce heads (Maniaji *et al.*, 2018) [4]. The lesser growth attributes (plant height – 138.37 cm, number of tillers hill^{-1} – 6.42, Leaf area index – 6.38 and dry matter production –9407 kg ha^{-1}) were recorded under seedlings transplanted at 25 x 10 cm and fertilized with 75 % RDF (30:22.5:37.5 kg NPK ha^{-1}). This could be due to narrow spacing with lesser nutrient availability which results in increased competition for resources resulted in poor growth compared to other planting geometry and NPK levels. These results are in accordance with the findings of Korir *et al.* (2018) [16] and Vimalan *et al.* (2019b) [32].

Yield Attributes and Yield

Yield attributes and yield of transplanted barnyard millet was significantly increased with planting geometry and NPK levels (Table 2). Adoption of 15 x 15 cm recorded significantly higher yield attributes (no. of earhead hill^{-1} - 4.64, length of earhead - 19.59 cm, weight of earhead - 13.70 g, no. of grains earhead^{-1} - 1067 and test weight - 3.85 g) and yields (grain - 2792 kg ha^{-1} and straw - 7805 kg ha^{-1}) of transplanted barnyard millet. This might be due to enhancement of yield attributing characters and yield in view of effective utilization of sun light, water, nutrient and increased in photosynthetic rate (Pramanik and Bera, 2013) [26]. The higher grain yield might be due to enhanced stature of yield attributes, thus forming larger sink size coupled with efficient translocation of photosynthates to the sink was noticed under optimum planting pattern with transplanting of medium aged seedlings. Optimum planting pattern is essential for proper utilization of resources in order to exploit the potential productivity of any crop (Prakasha *et al.*, 2018) [25]. The results are in accordance with the findings of Kalaraju *et al.* (2011) [14], Rajesh (2011) [27], and Kumar *et al*. (2019) [19]. This was followed by 20 x 20 cm which recorded yield attributes (no. of earhead hill^{-1} - 4.55, length of earhead -18.43 cm, weight of earhead - 13.41 g, no. of grains earhead^{-1} - 1046 and test weight- 3.83 g) and yields (grain- 2684 kg ha^{-1} and straw - 7694 kg ha^{-1}) of transplanted barnyard millet. Direct seeded barnyard millet (25 x 10 cm) registered lesser yield attributes and yield among different planting geometry. Among the various NPK levels, application of 150 % RDF (60:45:75 kg NPK ha-1) recorded higher yield attributes (no. of earhead hill-1 - 4.87, length of earhead -19.95 cm, weight of earhead - 13.91g, no. of grains earhead-1 - 1080 and test weight - 3.90 g) and yields (grain - 2830 kg ha-1and straw - 7895 kg ha-1) of transplanted barnyard millet, which was on par with application of 125 % RDF (50:37.5:62.5 kg NPK ha-1) recorded yield attributes (no. of earhead hill-1 - 4.79, length of earhead - 19.63 cm, weight of earhead - 13.79 g, no. of grains earhead-1 - 1069 and test weight - 3.87 g) and yields (grain - 2763 kg ha-1 and straw - 7843 kg ha-1) of

Table 2: Effect of planting geometry and NPK levels on yield attributes and yields barnyard millet

Treatments	No. of earhead hill^{-1}	Length of earhead (cm)	Weight of earhead (g)	No. of grains earhead^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Factor A– Planting Geometry (S)							
S_1	3.76	14.76	12.19	969	3.65	2361	7273
S_2	4.32	16.53	12.89	1014	3.76	2517	7508
S_3	4.47	18.16	13.26	1037	3.81	2627	7637
S_4	4.64	19.59	13.70	1067	3.85	2792	7805
S_5	4.55	18.43	13.41	1046	3.83	2684	7694
S. Ed.	0.04	0.18	0.12	9.97	0.03	42.29	47.26
CD (P = 0.05)	0.09	0.37	0.25	20.04	NS	85	95
Factor B – NPK levels (F)							
F_1	3.58	14.02	11.86	951	3.60	2310	7160
F_2	4.13	16.44	12.73	1005	3.75	2476	7435
F_3	4.79	19.63	13.79	1069	3.87	2763	7843

F_4	4.87	19.95	13.91	1080	3.90	2830	7899
S. Ed.	0.03	0.16	0.11	8.92	0.03	54.73	61.19
CD (P = 0.05)	0.08	0.33	0.22	17.92	NS	110	123
Interaction – S x F							
S_1F_1	3.50	12.23	11.42	939	3.55	2183	7014
S_1F_2	3.70	15.34	12.31	966	3.67	2397	7304
S_1F_3	3.90	15.69	12.45	980	3.68	2422	7383
S_1F_4	3.94	15.79	12.58	991	3.70	2443	7392
S_2F_1	3.54	13.07	11.82	947	3.58	2249	7129
S_2F_2	4.03	16.49	12.64	996	3.73	2450	7403
S_2F_3	4.81	18.23	13.50	1051	3.85	2650	7744
S_2F_4	4.91	18.35	13.60	1061	3.88	2717	7757
S_3F_1	3.58	14.47	11.97	951	3.61	2347	7180
S_3F_2	4.23	16.67	12.73	1004	3.77	2461	7445
S_3F_3	4.98	20.41	14.12	1093	3.91	2796	7930
S_3F_4	5.08	21.07	14.22	1099	3.95	2903	7992
S_4F_1	3.62	14.98	12.12	957	3.62	2379	7229
S_4F_2	4.37	17.01	13.06	1037	3.82	2547	7558
S_4F_3	5.24	23.14	14.70	1127	3.98	3078	8172
S_4F_4	5.31	23.23	14.90	1147	3.99	3133	8260
S_5F_1	3.68	15.23	12.26	961	3.65	2390	7247
S_5F_2	4.30	16.63	12.91	1022	3.78	2523	7463
S_5F_3	5.04	20.56	14.18	1095	3.92	2871	7988
S_5F_4	5.11	21.29	14.27	1104	3.96	2953	8076
S. Ed.	0.09	0.36	0.25	19.94	0.07	83.58	88.56
CD (P = 0.05)	0.18	0.73	0.50	40.07	NS	168	178

Of transplanted barnyard millet. The application of 150 percent RDF recorded significantly higher straw yield which was on par with 125 percent RDF and significantly superior over rest of the treatments. This might be due to better root activity, good source to sink relationship and high physiological activities which synthesized cytokinase (Kumar *et al.*, 2003, Deshmukh, 2007, Pradhan *et al*., 2011 and Raundal *et al*., 2017) [17, 8, 24 28]. The availability of higher levels of nitrogen to the crop might have helped in greater uptake and there by dry matter production and yield attributes was increased with levels of NPK application (Choudhary *et al*., 2008) [7]. Such improvement in yield was reported in foxtail millet with increased levels of N application (Jyothi *et al.,* 2015) [12]. The higher total dry matter production was attributed to better plant growth which resulted in higher dry matter accumulation and better translocation of photosynthates to ear heads during later stages. These results are in accordance with the findings of Maqsood *et al.* (2001) [19], Sharar *et al.* (2003) [30], Asghar *et al.* (2010) [2], Reddy and Reddy (2012) [29] and Charate *et al.* (2018). The application of 75 % RDF (30:22.5:37.5 kg NPK ha^{-1}) recorded lesser yield attributes and yield of barnyard millet among the various NPK levels. This might be due to inadequate supply of nutrients which results in lesser grain yield. These findings are in accordance with the findings of Prabudoss *et al.* (2014) [23]. Among the interaction effect, seedlings transplanted at 15 x 15 cm and fertilized with 150 % RDF (60:45:75 kg NPK ha^{-1}) recorded higher yield attributes (no. of ear head $hill^{-1}$ - 5.31, length of ear head - 23.23 cm, weight of ear head - 14.90 g, no. of grains ear $head^{-1}$ - 1147 and test weight - 3.99 g) and yields (grain - 3133 kg ha^{-1} and straw - 8260 kg ha^{-1}) of transplanted barnyard millet, which was on par with seedlings transplanted at 15 x 15 cm and fertilized with 125 % RDF (50:37.5:62.5 kg NPK ha^{-1}) which registered no. of ear head $hill^{-1}$ of 5.24, length of ear head of 23.14 cm, weight of ear head of 14.70 g, no. of grains ear $head^{-1}$ of 1127 and test weight of 3.98 g and caused the grain yield of 3078 kg ha^{-1} and straw yield of 8172 kg ha^{-1}.Wider spacing and adequate supply of plant nutrient helps in better photosynthesis and growth of millet which helps in higher grain yield. These results are in conformity with the findings of Kalaraju *et al.* (2009) [13], Shinggu *et al.* (2009) [31] and Prakasha *et al.* (2018) [25]. The lesser yield attributes (no. of ear head $hill^{-1}$ - 3.50, length of ear head - 12.23 cm, weight of ear head – 11.42 g, no. of grains ear $head^{-1}$ - 939 and test weight - 3.55 g) and yields (grain - 2183 kg ha^{-1} and straw - 7014 kg ha^{-1}) were recorded under seedlings planted at 25 x 10 cm and fertilized with 75 % RDF (30:22.5:37.5 kg NPK ha^{-1}). When plant density exceeds an optimum level with lesser availability of nutrients, competition among plants for light above the ground and nutrients below the ground becomes severe. The results are in accordance with the findings of Bayala *et al.* (2002) [3] and Divyashree *et al.* (2018) [9].

Conclusion

The experimental results civilized that there was noticeable variation on the productivity of transplanted barnyard millet due to adoption of different planting geometry and NPK levels. Transplanting of seedlings at 15 × 15 cm and fertilized with 150 % RDF – 60:45:75 kg NPK ha^{-1} (S_4F_4) produced better yield characters and yield. However, the treatment S_4F_3 (15 x 15 cm + 125 % RDF – 50:37.5:62.5 kg NPK ha^{-1}) was on par with S_4F_4 and it was economically viable. 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 and profitability of barnyard millet under transplanted conditions.

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