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RESEARCH ARTICLE

Influence Plant Geometry, Macro and Micro Nutrients on Yield and Nutrient uptake of Dual Purpose Sorghum under Rainfed Vertisols

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Abstract

Field experiment was conducted at Agricultural Research Station, Kovilpatti during *rabi* season (October 2017 to January 2018) to find out the suitable plant geometry, levels of fertilizers and foliar spray of micronutrients (Zn and Fe) at 15, 30 and 45 DAS to improve the growth and yield of sorghum variety K 12 (dual purpose). The experiment was laid out in randomized block design with three replication and twelve treatments. The treatment consists of two plant geometry, three different dose of fertilizer and foliar spray of micronutrients viz., 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS. The experimental results showed that reduced plant spacing of 30 × 15 cm together with enhanced application of 50:25:25 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DA S significantly increased the growth parameters *viz.,* plant height, stem girth and days to flowering. This attributes ultimately resulted in higher grain (3961 kg ha^{-1}) and stover (13972 kg ha^{-1}) yield of dual purpose sorghum compared to recommended practice of rainfed sorghum having 45 × 15 cm spacing and application of recommended 40:20:0 kg NPK ha^{-1} alone.

Keywords: *Plant spacing, Soil and Foliar nutrition, Growth and yield, Rainfed dual sorghum*

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the gifted grass genera of tropics and in India, it is popularly known as "Jowar". Its grains have about 10-12% protein, 3% fat and 70% carbohydrate. It provides food, feed and fuel to millions of poor farm families and their livestock in the arid and semi-arid tropical region of the world. India is one of the notable country for its higher livestock population and its economic integration with farm production, especially under the less mechanized dry land agriculture. Sorghum is most important crop to resource poor farmers for nutritional and livelihood security. The demand and consumption of agricultural crops for food, feed, and fuel is increasing at a globally rapid pace. Therefore, the production practices must be well optimized and managed to satisfy the growing worldwide demand. In more advanced agriculture the grain is used as a livestock feed while the whole crop is used as silage or forage (Cobley, 1976). The growth and yield of a crop can be adversely affected by deficient or excessive supply of any one of the essential nutrients. Soil application of nutrients will give the initial boost for growing seedlings (Hamayun *et al.*, 2011). Growth components like plant height, number of leaves, stem diameter, leaf area of fodder maize influenced significantly by the application of nitrogen and phosphorus (Ayub *et al.*, 2002). Hence this study was initiated with the objectives of determining the effect of different plant geometry, fertilizers levels and foliar spray of micronutrients on the performance of dual purpose sorghum under rainfed conditions.

Material and Methods

The field experiment was conducted at Agricultural Research Station, Kovilpatti during *rabi* (Oct 2017 – Jan 2018). The soil was clay loam in texture with pH of 8.04, EC of 0.45 dS m^{-1} and organic carbon content of 3.38 g kg^{-1}. The soil was low in available nitrogen (179 kg ha^{-1}), low in available phosphorus (10 kg ha^{-1}) and high in available potassium (365 kg ha^{-1}). The mean annual rainfall is 703 mm and the maximum and minimum temperature ranges from 34.9˚C and 22.8˚C, respectively. During the cropping period, the crop received 421.5 mm of rainfall in 17 rainy days and the maximum and minimum temperature ranges from 36.5˚C and 17.6˚C, respectively.

The experiment was laid out in randomized block design with three replication and twelve treatments. The treatment consists of two plant geometry, three different dose of fertilizer and foliar spray of micronutrients *viz.,* 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS. The sorghum variety K 12 (dual purpose) was chosen

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for this study. All agronomic practices like weed control, thinning, plant protection measures and harvesting as well as post harvest operation were made uniformly for all treatments. Various observation viz., plant height, stem girth, days to flowering, earhead length, earhead breadth, number of filled grains earhead^{-1}, test weight, grain and stover yield were recorded.

Results and Discussion

Effect of plant geometry, soil and foliar nutrition on growth parameters

Growth parameters of rainfed dual purpose sorghum was significantly influenced by adoption of different treatment combinations (Table 1). The plant height of various treatments ranged from 201.5 cm to 238.9 cm. The maximum plant height of 238.9 cm at harvest was recorded in the plant spacing of 30 × 15 cm with basal application of 50:25:25 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS. Competition for light might be the reason for increase in height due to closer intra-row spacing in sorghum. This was line with the results of Miko and Manga (2008). Increased nitrogen application also increased the plant height might be due to the progressive effect of nitrogen element on plant growth that leads to progressive increase in inter nodal length and consequently plant height. Similar results were reported by Gupta *et al*. (2008) and Nirmal *et al*. (2016).

Table 1. Effect of plant geometry, soil and foliar nutrition on plant height (cm), stem girth (cm) and days to flowering of rainfed dual purpose sorghum

Treatments			Plant height at harvest (cm)	Stem girth (cm)	Days to flowering (Days)
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	201.5	2.2	58.0
T_2		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	208.5	2.3	58.6
T_3		40:20:20 kg NPK ha^{-1}	216.4	2.3	59.0
T_4		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	222.8	2.7	60.0
T_5		50:25:25 kg NPK ha^{-1}	219.2	2.7	60.5
T_6		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	224.3	2.7	62.0
T_7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	205.1	2.1	58.0
T_8		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	212.1	2.2	59.0
T_9		40:20:20 kg NPK ha^{-1}	227.5	2.2	59.0
T_{10}		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	235.2	2.4	59.4
T_{11}		50:25:25 kg NPK ha^{-1}	231.2	2.4	59.7
T_{12}		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	238.9	2.4	61.0
SEd			6.72	0.072	1.20
CD (p=0.05)			14.10	0.15	NS

Among different spacing, 45 × 15 cm (T_1-T_6) recorded higher mean stem girth value of 2.48 cm than the closer spacing of 30 × 15 cm (T_7-T_{12}), which recorded the mean stem girth of 2.28 cm. The stem girth was higher in 45 × 15 cm spacing along with basal application of 50:25:25 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS, which recorded 2.7 cm. The reason for stem diameter reduction at higher plant densities can be linked to a reduction of assimilates allocation and more intra-plant competition among plant (Zand and Shakiba, 2013).

Earlier advancement of flowering was observed in the graded levels of NPK application under both the plant populations. Besides, foliar application of micronutrients (0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS) was found to delay the flowering in dual purpose rainfed sorghum than the basal application of NPK alone in irrespective of the sowing geometry. Days to flowering was not significantly influenced by different management options.

Dry matter production is basically a measure of photosynthetic efficiency of assimilatory system in plants. Plant spacing of 30 × 15 cm coupled with graded level of NPK @ 50:25:25 kg ha^{-1} + foliar spray of 0.5% $ZnSO_4$

Table 2. Effect of plant geometry, soil and foliar nutrition on drymatter production (kg ha^{-1}) of rainfed dual purpose sorghum

Treatments			Drymatter production (kg ha^{-1})		
			30 DAS	60 DAS	At harvest
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	1148	7492	12891
T_2		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1295	7710	13308
T_3		40:20:20 kg NPK ha^{-1}	1451	8152	13828
T_4		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1651	9397	15206
T_5		50:25:25 kg NPK ha^{-1}	1564	8806	14489
T_6		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1687	9691	15571
T_7	30 × 15 cm Spacing	40:20:0 kg NPK ha^{-1}(RDF)	1150	7515	13086
T_8		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1356	8045	13686
T_9		40:20:20 kg NPK ha^{-1}	1743	9848	15782
T_{10}		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1871	10794	17157
T_{11}		50:25:25 kg NPK ha^{-1}	1841	10583	16849
T_{12}		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	1987	11501	18254
SEd			45.89	305.04	512.29
CD (p=0.05)			94.17	632.61	1095.78

+ 0.2% $FeSO_4$ at 15, 30 and 45 DAS was found to accumulate more drymatter of 18254 kg ha^{-1} at harvest stage (Table 2). This might be due to enhanced nitrogen level which in turn consecutively resulted in more drymatter partitioning. Similar results were also reported by Singh *et al*. (2005).

Table 3. Effect of plant geometry, soil and foliar nutrition on grain yield, stover yield (kg ha^{-1}) and harvest index of rainfed dual purpose sorghum

Treatments			Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index*
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2572	10184	0.20
T_2		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2745	10423	0.21
T_3		40:20:20 kg NPK ha^{-1}	2905	10792	0.21
T_4		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3074	11896	0.21
T_5		50:25:25 kg NPK ha^{-1}	2942	11184	0.21
T_6		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3205	11996	0.21
T_7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2743	10238	0.21
T_8		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2803	10768	0.21
T_9		40:20:20 kg NPK ha^{-1}	3321	12032	0.22
T_{10}		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3716	13130	0.22
T_{11}		50:25:25 kg NPK ha^{-1}	3562	12876	0.22
T_{12}		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3961	13972	0.22
SEd			110.50	395.40	-
CD (p=0.05)			236.00	840.76	-

*Data are not statistically analysed.

Effect of plant geometry, soil and foliar nutrition on yield

The yield of rainfed dual sorghum K12 was significantly influenced by different plant geometry, graded levels of fertilizer and micronutrient foliar application (Table 3). Grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. A distinct enhancement in straw yield with increase in nutrient levels was evident from this study. Stover yield is directly proportional to plant population and drymatter accumulation in K 12 sorghum. Sowing at a plant spacing of 30 × 15 cm coupled with graded fertilizer level of 50:25:25 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS recorded significantly higher grain yield (3961 kg ha^{-1}) of rainfed sorghum. The increase in grain yield was due to higher growth attributes and drymatter production. Increase in yield of sorghum due to nitrogen application has also been reported by Obilana (1983) and Galbiatti *et al*. (1977). The recommended practices for rainfed sorghum having 45 × 15 cm spacing with basal application of 40:20:0 kg NPK ha^{-1} recorded 35.0 per cent reduced grain yield compared to the above said best treatment.

Stover yield of rainfed sorghum was also significantly influenced by plant spacing, nutrient levels and foliar spray. Sowing at 30 × 15 cm with higher levels of NPK @ 50:25:25 kg ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS recorded significantly higher stover yield of 13972 kg ha^{-1} (Table 3). The significant increase in stover yield with increased fertilizer levels was due to fact that all these nutrients were involved in increasing protoplasmic constituents, root, shoot growth and accelerating the process of cell division, enlargement and elongation which in turn showed luxuriant vegetative growth and resulted in higher green and dry fodder yield. Similar results were also obtained by Kumar and Chaplot (2015) and Rana *et al*. (2013).

Table 4. Effect of plant geometry, soil and foliar nutrition on economics of rainfed dual purpose sorghum

Treatments			Cost of cultivation (₹ha^{-1})	Gross return (₹ha^{-1})	Net return (₹ha^{-1})	B:C ratio
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	27962	43678	15717	1.56
T_2		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	30772	46576	15805	1.51
T3		40:20:20 kg NPK ha^{-1}	28346	47595	19249	1.68
T4		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	31156	53453	22297	1.68
T5		50:25:25 kg NPK ha^{-1}	29304	49327	20023	1.68
T6		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	32114	55949	23835	1.74
T7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	28187	46610	18424	1.65
T8		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	30997	49955	18959	1.61
T9		40:20:20 kg NPK ha^{-1}	28571	57064	28493	2.00
T10		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	31381	63771	32390	2.03
T11		50:25:25 kg NPK ha^{-1}	29529	59804	30275	2.03
T12		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	32339	67252	34913	2.08

*Data are not statistically analysed.

Economics

Adoption of closer plant geometry, soil application of graded levels of fertilizer and foliar micro nutrition was more profitable in terms of gross return, net return and B: C ratio (Table 4).

Higher net income and benefit cost ratio was obtained when sorghum sown with a spacing of 30 × 15 cm besides application of 50:25:25 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS which recorded ₹ 34,913 ha^{-1} and 2.08, respectively. This could be ascribed to higher grain and stover yield at higher rate of NPK fertilization. Similar results were also reported by Singh *et al.* (2010) and Kumar *et al.* (2015) in baby corn.

Conclusion

From the experimental results, it is concluded that cultivation of dual sorghum variety K 12 at 30 × 15 cm spacing + basal application of 50:25:25 kg NPK ha^{-1} along with foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS is a viable package for getting higher yield and higher income in rainfed vertisols.

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