International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(3): 794-798

Received: 08-03-2020
Accepted: 10-04-2020

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Influence of plant spacing, nutrient levels and foliar nutrition on growth, yield and quality of dual purpose sorghum K12 under rainfed condition

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DOI: https://doi.org/10.22271/chemi.2020.v8.i3j.9299

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 K12 (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% FeSO4 at 15, 30 and 45 DAS. Observation on growth parameters, grain yield, stover yield, fodder qualities and Rainfall use efficiency were recorded. The experimental results shows 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 DAS significantly increased the growth parameters *viz*., plant height, stem girth days to flowering and drymatter production. 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: Rainfed, dual sorghum, plant spacing and nutrient management, growth and yield

Introduction
Sorghum is one of the grass genera of tropics and in India, it is popularly known as “Jowar”. 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. Livestock plays a vital role in improving the Indian economy. The livestock population is expected to grow at the rate of 0.55% in the coming years, and the population is likely to be around 781 million by 2050. Though India is the leading producers of milk, meat and eggs among countries, due to improper nutrition and inadequate health-care and management the productivity of animals is 20-60% lower than the global average. Half of the total losses in livestock productivity are contributed to the inadequacy in supply of feed and fodder. 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) [2]. Moreover the fodder production in the country is not sufficient and that are mostly of poor quality due to improper nutrient management under dryland condition. Presently the availability of green fodder is 462 mt. and the dry fodder is 394 mt. and facing a net deficit of 35.6% green fodder, 10.95% dry crop residues and it will reach to 1,012 and 631 million tonnes by the year 2050 (Vishvakumari *et al.*, 2017) [15]. On the other hand, the area under fodder crops is stagnant since last two-three decades. There should be enough research focus to work on new strategies and meet the demand.
The growth and yield of any 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) [5].

(Hamayun *et al.*, 2011) [5]. Growth components like plant height, number of leaves, stem diameter, leaf area of fodder crops influenced significantly by the application of optimum dose of fertilizers.

Rana *et al.* (2012) [11] reported that application of 150 per cent RDF produced significantly higher plant height, number of tillers, green fodder yield and drymatter yield of sorghum over lower levels of fertilizer. However in rainfed agriculture, nutrient uptake by the crop plants is primarily decided by the soil available moisture. Under this condition, foliar nutrition considered as the important method of fertilization. Nutrients supplied through foliar nutrition are utilized by the plants more quickly than the soil application. Application of nutrients through the foliage is quickly correcting plant nutrient deficiencies, when identified on the plant (Rajasekar *et al.*, 2017) [10]. Hence the present investigation was carried out to develop specific management practices such as nutrient management including foliar spray of micro nutrients under different plant spacing to enhance the yield and productivity of rainfed dual purpose sorghum.

Materials and methods

The field experiment was conducted at Agricultural Research station (Tamil Nadu Agricultural University), Kovilpatti, Tamil Nadu 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 treatments consist of two plant geometry, three graded levels fertilizer and foliar spray of micronutrients (Zn and Fe) *viz*., T_1 - 45 × 15 cm spacing + 40:20:0 NPK kg ha^{-1}(Control – Recommended practices), T_2 - 45 × 15 cm spacing 40:20:0 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$, T_3 - 45 × 15 cm spacing + 40:20:20 NPK kg ha^{-1},T_4 - 45 × 15 cm spacing 40:20:20 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$,T_5 - 45 × 15 cm spacing + 50:25:25 NPK kg ha^{-1},T_6 - 45 × 15 cm spacing 50:25:25 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$,T_7 - 30 × 15 cm spacing + 40:20:0 NPK kg ha^{-1}(RDF), T_8 - 30 × 15 cm spacing 40:20:0 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$, T_9 - 30 × 15 cm spacing + 40:20:20 NPK kg ha^{-1},T_{10} - 30 × 15 cm spacing 40:20:20 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$,T_{11} - 30 × 15 cm spacing + 50:25:25 NPK kg ha^{-1},T_{12} - 30 × 15 cm spacing + 50:25:25 NPK kg ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$. NPK fertilizers applied as basal and the foliar spray of micronutrients was given at 15, 30 and 45 DAS. The dual purpose sorghum variety K 12 was chosen for this study. All agronomic practices like weed control, thinning, plant protection measures and harvesting as well as postharvest operation were made uniformly for all treatments. Various observation *viz*., plant height, stem girth, days to flowering, grain yield, stover yield, fodder quality like Crude protein content and Crude fibre content and Rainfall use efficiency were recorded.

Result and discussion

Effect of treatments 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 dual sorghum by 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 together with basal application of graded levels of fertilizer dose 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 responsible for increase in height due to closer intra-row spacing in sorghum. This finding was agrees with the results of Miko and Manga, 2008 [7]. 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) [4] and Nirmal *et al.* (2016) [8]. However, it was at par with the plant spacing of 30 × 15 cm + graded levels of NPK @ 50:25:25 kg ha^{-1} alone (T_{11}) or 40:20:20 kg NPK ha^{-1} along with foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS (T_{10}). Sowing of K 12 sorghum at 45 × 15 cm spacing + recommended 40:20:0 kg NPK ha^{-1} (T_1) recorded lower plant height of 201.5 cm at harvest stage.

Controversy, following of 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 maximum in sowing at 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 plants (Zand and Shakiba, 2013) [16]. The lower stem girth was noticed in 30 × 15 cm spacing + 40:20:0 kg NPK ha^{-1} as basal without foliar spray.

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. Sorghum K12 was early flowering type variety. Usually flowering arises 60 days after sowing. Adoption of different plant spacing, graded level of fertilizer and micronutrient foliar application delayed the flowering in the treatments receiving higher level of nutrients and foliar spray of micronutrients in reduced plant populations. This could be related to the supportive effects of more available fertilizers to lower number of plants unit $area^{-1}$ which permitted building of more vigorous growth that resulted in higher number of days to flowering. More plant density resulted inter competition increased and early flowering. These results were close conformity with Zand and Shakiba, (2013) [16]. Dry matter production is basically a measure of photosynthetic efficiency of assimilatory system in plants. Plant spacing of 30 × 15 cm coupled with basal application of graded level 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 was found to accumulate more dry matter of 18254 kg ha^{-1} at harvest stage. This may be due to increase in nitrogen level having resulted in more active plant growth, which consecutively resulted in more dry matter partitioning. Similar results were reported by Singh *et al*. (2005) [14]. It was followed by 30 × 15cm plant spacing + 40:20:20 kg NPK ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS (T_{10}) at all the stages of observation. Sorghum sown at 45 × 15 cm spacing +

recommended dose of 40:20:0 kg NPK ha^{-1} (T_1) observed lower drymatter accumulation of 12891 kg ha^{-1}at harvest stage.

Effect of treatments 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 2). 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.

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% ZnSO4 + 0.2% FeSO4 at 15, 30 and 45 DAS recorded significantly higher grain yield (3961 kg ha^{-1}) of rainfed sorghum. The increase in grain yield could be as a result of good drymatter production for grain filling as a result of higher number of leaves. Increase in yield of sorghum also due to nitrogen application and has been reported by some workers, Obilana (1983) [9] and Galbiatti *et al*. (1977) [3].

Application of NPK at 50:25:25 kg ha^{-1} + foliar spray of 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS (T_6) with a plant spacing of 45 × 15 recorded statistically comparable grain yield under the plant spacing of 30 × 15 cm + 40:20:20 kg of NPK ha^{-1} without foliar spray (T_9).

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.

A distinct enhancement in straw yield with increase in nutrient levels was evident of this study. Stover yield is directly proportional to plant population and drymatter accumulation in K12 sorghum. 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 2). The significant increase in fodder yield with increasing fertility 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) [6] and Rana *et al*. (2013) [12]. The recommended spacing of 45 × 15 cm + basal application of NPK @ 40:20:0 kg ha^{-1} (T_1) recorded lower stover yield of 10184 kg ha^{-1} and it was 27.1 per cent lower yield than T_{12} treatment.

Crude protein and crude fibre

The crude protein content of dual purpose rainfed sorghum was not much influenced by different plant geometry, modified levels of NPK and foliar spray of micronutrient (Table 3).

Higher crude protein content was observed in 30 × 15 cm spacing with basal application 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 (T_{12}) recorded 3.04 per cent. However, it was on par with the treatment having either 50:25:25 kg NPK ha^{-1} or 40:20:20 kg NPK ha^{-1} coupled with foliar spray of micronutrients under both the plant spacing. The recommended practice of rainfed sorghum sown at 45 × 15 cm + recommended dose of 40:20:0 kg NPK ha^{-1} (T_1) recorded lower crude protein content of 2.78 per cent only.

Similarly adoption of various plant geometry, graded levels of fertilizer and micro nutrient foliar spray did not influence much variation on the crude fibre content of dual purpose rainfed sorghum (Table 3).

Plant spacing of 30 × 15 cm + basal application 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 (T_{12}) recorded higher crude fibre content of 14.64 per cent. However it was on par with the same plant spacing coupled with 40:20:20 kg NPK ha^{-1} + foliar spray of micronutrients with a crude fibre production of 14.22 per cent. The recommended practice of rainfed sorghum sown at 45 × 15 cm coupled with recommended dose of NPK @ 40:20:0 kg ha^{-1} (T_1) recorded lower crude fibre content (10.69 per cent).

Inclusion and application of potash fertilizer in rainfed sorghum positively augmented the crude protein and crude fibre content than the sorghum cultivated with RDF where potash fertilizer is not recommended. Sadhu *et al.* (1991) [13] and Ayub *et al.* (1999) [1] also gave their conformity results with increase in crude protein through increment in nitrogen doses was due to increased absorption of nitrogen. Since nitrogen is main constituent of amino acids, it ultimately increased crude protein content of plants.

Rainfall use efficiency (RUE)

Influence of different treatments on rainfall use efficiency of dual purpose sorghum K12 was appreciable (Table 3).

Sorghum sown at 30 × 15 cm with application of graded fertilizer dose 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 (T_{12}) registered higher rainfall use efficiency of 9.40 kg mm^{-1} ha^{-1}. It was followed by 30 × 15 cm spacing + application of 40:20:20 kg NPK ha^{-1} + foliar spray of micronutrients recorded the RUE of 8.82 kg mm ha^{-1}. The lower rainfall use efficiency was found in the recommended practice of 45 × 15 cm spacing with basal application of 40:20:0 kg NPK ha^{-1} recorded 6.10 kg of sorghum grain mm ha^{-1}.

Table 1: Effect of plant geometry, macro and micro nutrients on growth parameters of dual sorghum

Treatments			plant height at harvest (cm)	Stem girth at harvest (cm)	Days to flowering	Drymatter production at harvest (kg/ha)
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	201.5	2.2	58.00	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	208.5	2.3	58.60	13308
T_3		40:20:20 kg NPK ha^{-1}	216.4	2.3	59.00	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	222.8	2.7	60.00	15206
T_5		50:25:25 kg NPK ha^{-1}	219.2	2.7	60.50	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	224.3	2.7	62.00	15571
T_7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	205.1	2.1	58.00	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	212.1	2.2	59.00	13686
T_9		40:20:20 kg NPK ha^{-1}	227.5	2.2	59.00	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	235.2	2.4	59.40	17157
T_{11}		50:25:25 kg NPK ha^{-1}	231.2	2.4	59.70	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	238.9	2.4	61.00	18254
SEd			6.72	0.072	1.20	512.29
CD (p=0.05)			14.10	0.15	NS	1095.78

Table 2: Effect of plant geometry, macro and micro nutrients on yield of dual sorghum

Treatments			Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2572	10184
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
T_3		40:20:20 kg NPK ha^{-1}	2905	10792
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
T_5		50:25:25 kg NPK ha^{-1}	2942	11184
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
T_7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2743	10238
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
T_9		40:20:20 kg NPK ha^{-1}	3321	12032
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
T_{11}		50:25:25 kg NPK ha^{-1}	3562	12876
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
SEd			110.50	395.40
CD (p=0.05)			236.00	840.76

Table 3: Effect of plant geometry, macro and micro nutrients on quality of dual sorghum and RUE

Treatments			Crude Protein (%)	Crude Fibre (%)	RUE (kg ha mm^{-1})
T_1	45 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2.78	10.69	6.10
T_2		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2.86	11.19	6.51
T_3		40:20:20 kg NPK ha^{-1}	2.89	12.07	6.89
T_4		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2.94	12.63	7.29
T_5		50:25:25 kg NPK ha^{-1}	2.91	12.43	6.98
T_6		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2.96	13.01	7.60
T_7	30 × 15 cm spacing	40:20:0 kg NPK ha^{-1}(RDF)	2.80	10.91	6.51
T_8		40:20:0 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	2.83	11.59	6.65
T_9		40:20:20 kg NPK ha^{-1}	3.00	13.44	7.88
T_{10}		40:20:20 kg NPK ha^{-1}+ FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3.03	14.22	8.82
T_{11}		50:25:25 kg NPK ha^{-1}	3.01	13.74	8.45
T_{12}		50:25:25 kg NPK ha^{-1} + FS 0.5% $ZnSO_4$ + 0.2% $FeSO_4$ at 15, 30 and 45 DAS	3.04	14.64	9.40
SEd			0.09	0.36	-
CD (p=0.05)			0.21	0.85	-

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