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Yield, nutrient content, nutrient uptake and economics of sorghum [*Sorghum bicolor* (L.) Moench] genotypes as affected by different fertility levels

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Abstract
A field experiment was conducted at Rajasthan College of Agriculture, Udaipur during *kharif* season of 2016 to evaluate yield, nutrient content, nutrient uptake and economics of sorghum [*Sorghum bicolor* (L.) Moench] genotypes as affected by different fertility levels. Treatments comprised of three fertility levels, viz. 75%, 100% and 125% recommended dose of fertilizers (RDF 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}) with five different types of genotypes, viz. CSH 14, SPV 2293, SPV 2308, SPV 2307 and CSV 17 were laid out in factorial randomized block design and were replicated thrice. Among the different genotypes, csh 14 exhibited significant superiority in terms of grain yield (4230 kg ha^{-1}) and maximum harvest index (32.53%) was reported in case of CSV 17, however highest stover yield (12707 kg ha^{-1}) and biological yield (15940 kg ha^{-1}) were recorded in SPV 2293. The highest N and P content in grain and stover & K content in stover were recorded in CSH 14. While, highest K content in grain was recorded in CSV 17. Genotype CSH 14 recorded maximum N, P, K uptake in grain and total N and total P uptake; however, SPV 2293 recorded highest N, P, K uptake in stover and total K uptake. The highest net return (₹ 65266 ha^{-1}) and B: C ratio (2.95) was found in CSH 14. Treatment with 125% RDF recorded significantly higher grain, stover and biological yield over 75% and 100% RDF. However, harvest index was found non-significant to different fertility levels. 125% RDF provided significantly higher N, P & K content in grain as well as in stover over the lower doses i.e., 75% and 100% RDF while, both these doses were found statistically at par with each other. 125% RDF significantly improved N, P & K uptake by grain, stover and total uptake by crop over 75% and 100% RDF. 125% RDF also recorded significantly higher net return and B: C ratio over both the lower doses.

Keywords: Yield, economics, nutrient content, nutrient uptake, fertility levels, sorghum genotypes

Introduction
Sorghum [*Sorghum bicolor* (L.) Moench] is the fourth important food crop in the country after rice, wheat and maize. It is also known as the king of millets. It is not only used as the staple food but also used as fodder in order to make animal husbandry sector more viable, as per requirement. Among the sorghum growing countries, India ranks fourth in production after USA, Mexico and Nigeria while USA being the largest producer in the world (FAO, 2016) [7]. Other major sorghum growing countries includes China, Argentina, Sudan, Canada, Indonesia & Paraguay. Its nutritional value is also high, viz. 9.35% protein, 3.35% fat, 72.41% carbohydrate and moisture content 10.66% (Adebiyi *et al.*, 2005) [1]. In India, the area under sorghum occupies approximately 5.30 million hectare with an annual production of about 5.05 million tonnes and an average productivity of 953 kg ha^{-1} (Ministry of Statistics, 2016) [2]. Sorghum is mainly grown in Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Gujarat and Rajasthan. The reason for low productivity of sorghum seems to be non-adoption of proper agro techniques *viz.* using poor & old genotypes, inadequate use of fertilizer, inadequate plant population and plant protection measures. However, the production can be increased by adopting improved package of practices including suitable genotype, optimum plant geometry and appropriate fertilization. Considering these facts, research efforts have been made to achieve substantial increase in sorghum productivity through evolving better genotypes and dissemination of appropriate production technologies. But, still a wide gap exists between realizable yield and that obtained at the farmers end.

Amongst growth factors, adequate supply of chemical fertilizers especially N, P and K is considered to be of prime importance due to its profound impact on various aspects of growth and development, hence productivity of the crop. Balanced use of fertilizer plays a key role in modernization of Indian agriculture. It is estimated that almost 40 per cent of the total food grain output can be directly attributed to fertilizer use. Nitrogen is indispensable for increasing crop production as it is the major constituent of proteins and chlorophyll and is associated with the activity of every living cells, coupled with greater volatilization and leaching losses. Phosphorus plays the active role in energy production, storage and transfer. It also helps in photosynthesis, respiration, root growth and tolerance against root diseases, plant reproduction and seed formation. Phosphorus fixation in both acidic and alkaline soils is one of the major problems and hence, by proper method, amount and time of application of fertilizer we can improve the yield. Potassium promotes photosynthesis, transport of photosynthates, enhances efficiency of nitrogen use and formation of protein. It makes the plant more resistant to diseases and lodging. Drought stress reducing the yield components, especially the number of panicles per plant, one-hundred grain weight and total grain yield compared to obtained at full irrigation. Potassium sulfate increased grain and biological yield of sorghum by 28% and 22%, respectively compared to control through improving growth conditions (Mohammad *et al.,* 2011) [11]. Inspite of this, farmers seldom apply full recommended dose of nitrogen, phosphorous and potassium to sorghum crop due to high cost of fertilizers, because marginal and small farmers have very meager financial resources to purchase the required quantity of fertilizers. Sorghum being a *kharif* crop, farmers does not take the risk of applying any chemical fertilizers at its full recommended dose. Since optimum dose of nitrogen, phosphorous and potassium is dependent on several factors like soil, crop, environment and crop growing situations and thus it necessitates the working out of economic and viable doses of fertilizers. The development of elite genotypes is a continuous process and currently many genotypes of different maturity groups have been evolved. Therefore, it is important to assess the response of fertility levels to these elite genotypes. Keeping in view of above consideration, present study was conducted during *kharif* season of 2016.

Materials and Methods

The experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur. The soil of experimental site was clay loam in texture, having slightly alkaline reaction (pH 7.9), medium in available nitrogen (295.8 kg ha^{-1}) and phosphorus (19.5 kg ha^{-1}) and high in available potassium (346.2 kg ha^{-1}). The experiment comprised of 15 treatment combinations, which consists of five grain sorghum genotypes (SPV 2293, SPV 2308, SPV 2307, CSV 17 and CSH 14) and three fertility levels (60 kg N ha^{-1}+30 kg P_2O_5 ha^{-1}+30 kg K_2O ha^{-1}, 80 kg N ha^{-1}+40 kg P_2O_5 ha^{-1}+40 kg K_2O ha^{-1}, 100 kg N ha^{-1}+50 kg P_2O_5 ha^{-1}+50 kg K_2O ha^{-1}). The experiment was laid out in a factorial randomized block design with factorial concept and were replicate thrice. Sorghum varieties were sown on 8th July, 2016 in rows, using seed rate of 10 kg ha^{-1} having 45 cm row to row distance and maintain plant to plant spacing of 15 cm. Fertilizer application was made as per the treatment. Full dose of phosphorus, potash and half dose of nitrogen were applied at the time of sowing in the form of urea, DAP and MOP as basal application. The quantity of nitrogen supplied through DAP was adjusted with urea. The remaining dose of nitrogen was supplied by placement through urea at 30 DAS. After thorough sun drying of the harvested bundles from each net plot was collected and then their weight were taken for biological yield and then calculated in terms of kg ha^{-1}. Grain yield of each net plot was recorded separately and finally calculated in terms of kg ha^{-1}. Grain yield was subtracted from total biological yield in each net plot and expressed in terms of kg ha^{-1}. Harvest index was calculated by using the formula given by Donald and Hamblin (1976) [5].

$$\text{Harvest index (HI)} = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \text{ X } 100$$

The plant samples collected at harvest from each net plot were dried in oven at 65ºC for 72 hrs, and were grinded separately to pass through 40 mesh size. From each sample, the required quantity was weighed separately for chemical analysis to determine nitrogen, phosphorus and potassium by adopting following standard methods (Table 3.5).

Table 3.5: Methods used for chemical analysis of crop plant after harvest

Content	Methods used and reference
a. Nitrogen	Nessler's reagent colorimetric method (Snell and Snell, 1959) [14]
b. Phosphorus	Ammonium vanado-molybdate yellow colour method (Richards, 1968) [13]
c. Potassium	Flame photometer (Jackson, 1973) [8]

Nitrogen, phosphorus and potassium uptake by the crop were calculated by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) x grain and stover yield (kg ha}^{-1})}{100}$$

To ascertain the most remunerative treatment, economics of different treatments were worked out in terms of net returns (₹ ha^{-1}), which was computed by deducting the cost of cultivation from income per ha fetched by the respective treatment. B: C ratio was also calculated treatment-wise to ascertain economic viability of the treatments by using following formula:

$$\text{B: C ratio} = \frac{\text{Net return (₹ ha}^{-1})}{\text{Total cost (cost of cultivation + cost of treatments) (₹ ha}^{-1})}$$

The data collected during the course of investigation were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Fisher (1950) [6]. The critical difference for the treatment comparison was worked out, wherever the F-test was found significant at 5 per cent level of significance. To assess the relationship between various characters, correlation coefficients were computed. Further, in order to establish cause and effect relation, regression equations were worked out. All these statistical estimates were computed by standard statistical procedures (Panse and Sukhatme, 1985) [12].

Table 1: Effect of sorghum genotypes and different fertility levels on yield and economics.

Treatments	Yield (kg ha^{-1})			Harvest index (%)	Net return (₹ ha^{-1})	B/ C Ratio
	Grain	Stover	Biological			
Genotypes						
SPV 2293	3234	12707	15940	20.29	54435	2.46
SPV 2308	3156	12690	15845	19.91	53311	2.40
SPV 2307	3028	12310	15337	19.74	50590	2.28
CSV 17	3318	6882	10200	32.53	41041	1.85
CSH 14	4230	11521	15751	26.85	65266	2.95
SEm±	92.2	407.7	443.8	0.76	1855	0.08
CD (P= 0.05)	267.1	1181.1	1285.6	2.20	5373	0.24
Fertility levels (% of RDF)						
75	3007	10024	13031	23.08	45624	2.16
100	3494	11326	14819	23.57	54583	2.47
125	3678	12316	15993	22.99	58578	2.53
SEm±	71.74	315.8	343.8	0.59	1437	0.06
CD (P= 0.05)	206.9	914.8	995.9	NS	4162	0.18

(RDF – 80 kg N + 40 kg P_2O_5 +40 kg K_2O)

Table 2: Effect of sorghum genotypes and different fertility levels on nutrient content and uptake in grain and stover

Treatments	Nutrient content (%)						Nutrient uptake (kg ha^{-1})								
	Nitrogen		Phosphorus		Potassium		Nitrogen			Phosphorus			Potassium		
	Grain	Stover	Grain	Stover	Grain	stover	Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
Genotypes															
SPV 2293	1.711	0.555	0.346	0.236	0.560	1.663	55.33	70.63	125.96	11.22	29.99	41.20	18.10	211.47	229.57
SPV 2308	1.662	0.548	0.342	0.236	0.555	1.660	52.37	69.65	122.02	10.81	29.98	40.78	17.54	211.05	228.59
SPV 2307	1.691	0.538	0.340	0.231	0.525	1.656	51.15	66.42	117.57	10.30	28.43	38.73	15.92	203.85	219.77
CSV 17	1.695	0.547	0.332	0.237	0.562	1.657	56.30	37.76	94.06	11.03	16.30	27.33	18.69	114.13	132.81
CSH 14	1.731	0.557	0.350	0.237	0.561	1.682	73.23	64.34	137.57	14.79	27.32	42.11	23.76	193.99	217.75
SEm±	0.011	0.004	0.002	0.001	0.007	0.006	1.50	2.37	3.23	0.35	0.98	1.14	0.55	6.87	7.02
CD (P= 0.05)	0.031	0.013	0.007	0.003	0.019	0.018	4.34	6.86	9.35	1.03	2.85	3.31	1.60	19.91	20.35
Fertility levels (% of RDF)															
75	1.679	0.532	0.337	0.233	0.537	1.625	50.48	53.44	103.92	10.17	23.36	33.53	16.17	162.86	179.03
100	1.702	0.553	0.344	0.236	0.553	1.682	59.56	62.66	122.22	12.04	26.76	38.80	19.36	190.32	209.68
125	1.712	0.562	0.345	0.237	0.567	1.684	63.00	69.17	132.17	12.68	29.08	41.76	20.87	207.52	228.39
SEm±	0.008	0.003	0.002	0.001	0.005	0.005	1.16	1.84	2.50	0.27	0.76	0.89	0.43	5.32	5.44
CD (P= 0.05)	0.024	0.010	0.006	0.002	0.015	0.014	3.36	5.32	7.24	0.79	2.21	2.57	1.24	15.42	15.76

(RDF – 80 kg N + 40 kg P_2O_5 +40 kg K_2O)

Result and Discussion

The results obtained from the present investigation are presented in Table 1 and 2.

Yield and harvest index

csh 14 exhibited significant superiority in terms of grain yield (4230 kg ha^{-1}) and harvest index (32.53%) was reported higher in CSV 17, however, highest stover yield (12707 kg ha^{-1}) and biological yield (15940 kg ha^{-1}) were recorded in SPV 2293. The higher grain yield by CSH 14 and stover yield by SPV 2293 was registered as compared to rest of the genotypes. This appears to be a result of remarkable improvement in different yield components, which was brought about due to adoption of genotypes. Such close association ship of grain yield with different yield components was also observed by Dhaker (2010) [3] and Mawliya (2012) [10]. 125% RDF significantly increased the grain, stover and biological yields over 75% and 100% RDF. In the preceding section, it was well emphasized that increasing rate of fertilizer, markedly improved overall growth of the crop. The increased availability of nutrients and photosynthates might have enhanced in most of the cereals, greater assimilating surface at reproductive development stage results in better grain formation because of adequate production of metabolites and their translocation towards grain. The results of present investigation are in close conformity with the findings of Kaushik and Shaktawat (2005) [9] and Singh and Sumeriya (2006) [16].

Nutrient Content

The data presented in Table revealed that among genotypes tested, CSH 14 brought about significantly higher N content in grain and stover over rest of the genotypes except SPV 2293 where it was found statistically at par with CSH 14. Genotypes CSH 14 recorded the highest N content in stover (0.557%) as compare to rest of the genotypes. Genotypes CSH 14 and SPV 2293 recorded significantly higher P content in grain as compare to the rest of the genotypes. However, both of these were found to be statistically similar with each other. Genotype CSH 14, CSV 17, SPV 2293 and SPV 2308 recorded statistically higher P content in stover over SPV 2307. Data revealed that among genotypes tested, CSV 17 recorded higher K content in grain at harvest over all the genotypes except SPV 2307 where it was found to be non-significant**.** CSH 14 recorded significantly higher K content as compare to rest of the genotypes. However, other genotypes were found at par with each other. Genotype CSH 14 accumulated significantly higher N in grain over rest of the genotypes. The significant increase in N, P and K content of grain and stover at harvest seems to be on account of capabilities of genotypes for efficient absorption, translocation and utilization of mineral nutrients. The increased content of N & P in grain was expected as most of nutrients translocated from vegetative parts towards grain (sink). The results are in close conformity with the findings of Dixit *et al*. (2005) [4]. The data indicates that application of 100% and 125% RDF significantly increased N content in grain and stover over 75% RDF but found at par with each other. The application of 100% and 125% RDF significantly increased P content in grain and stover over 75% RDF but found at par with each other and also with application of 100% and 125% RDF recorded significantly higher K content in grain and stover over 75% RDF, but found at par with each other. Increased nutrient concentration in grain with fertilizer application could be due to greater mobilization of nutrients from vegetative parts to grain. The total content of N, P and K increased significantly due to fertilizer application is in agreement with the findings of Sumeriya *et al*. (2005), Dixit *et al*. (2005) [4].

Nutrient Uptake

An examination of data revealed that genotype CSH 14 accumulated significantly higher N in grain and total N over rest of the genotypes but genotypes SPV 2293, SPV 2308, SPV 2307 and CSH 14 accumulated significantly higher N in stover over CSV 17. However, they were found at par with each other. Also, CSH 14 recorded significantly higher uptake of phosphorus by grain (14.79 kg ha^{-1}) and total P over rest of the genotypes. Whereas, genotype SPV 2307 had minimum phosphorus uptake by grain (10.30 kg ha^{-1}) but SPV 2293 recorded significantly superior P value in stover over CSV 17 but found at par with the rest of the genotypes. CSH 14 recorded maximum potassium uptake by grain (18.69 kg ha^{-1}) which was significantly higher over rest of the genotypes. However, the genotype SPV 2293, SPV 2308, SPV 2307 and CSH 14 recorded significantly higher potassium uptake by stover over CSV 17 but found at par with each other. The genotype SPV 2293 significantly increased higher total K uptake over CSV 17 by 72.86 per cent but found at par over rest of the genotypes. A critical examination of data showed that application of 125% RDF significantly increased nitrogen uptake of grain by 24.80 and 5.77 per cent over 75 and 100% RDF, respectively. Application of 100% RDF also increased N uptake by 17.99 per cent in grain. The increase in uptake by stover with the 125% RDF was by 29.43 and 10.38 per cent over 75% and 100% RDF, respectively. Application of 125% RDF significantly increased total N uptake by 27.18 and 8.18 per cent over 75% and 100% RDF, respectively. However, application of 100% RDF also increased total N uptake by 17.61 per cent over 75% RDF. Application of 125% RDF resulted in significantly higher phosphorus uptake (29.08 kg ha^{-1}) by grain by 24.68 per cent over 75% RDF but found at par with 100% RDF in this respect. It is cleared from the data that application of 125% RDF recorded significantly higher phosphorus uptake (29.08 kg ha^{-1}) by stover. Application of 125% RDF recorded significantly higher phosphorus uptake by 24.48 and 8.67 per cent over 75% and 100% RDF, respectively. Further, 100% RDF also recorded significantly higher P uptake by 14.55 per cent over 75% RDF. Application of 125% RDF significantly increased total P uptake by 24.54 and 7.63 per cent over 75% and 100% RDF, respectively. However, application of 100% RDF increased total P uptake by 15.71 per cent over 75% RDF. A critical examination of data showed that application of 125% RDF significantly improved the potassium uptake of grain to the tune of 29.06 and 7.79 per cent over 75% and 100% RDF, respectively. Application of 100% RDF fertility level also significantly increased K uptake by 15.72 per cent over 75% RDF. The data showed that application of 125% RDF significantly improved the potassium uptake by 27.42 and 8.93 per cent over 75% and 100% RDF, respectively. Further application of 100% RDF also significantly increased K uptake by 16.88 per cent over 75% RDF. An assessment of data revealed that application of 125% RDF significantly increased total K uptake by 27.57 and 8.92 per cent over 75% and 100% RDF, respectively. However, application of 100% RDF also increased total K uptake by 17.12 per cent. The uptake of nutrients is mainly governed by the variation in grain and stover yield and their nutrient concentrations. Variation in uptake by grain, stover and total uptake of nitrogen, phosphorus and potassium by crop was significantly affected due to genotypes. Genetic variability in sorghum with respect to uptake of N, P and K was also observed by Sumeriya (2010) [15] and Mawaliya (2012) [10].

Net return and B: C ratio

It can be inferred from the data that CSH 14 recorded maximum net return (₹ 65266 ha^{-1}) which was significantly higher over rest of the genotypes, followed by genotype SPV 2293, SPV 2308, SPV 2307 and CSV17. The increase in net return with genotype CSH 14 was of the magnitude of 19.90, 22.43, 29.00 and 59.03 per cent over SPV 2293, SPV 2308, SPV 2307and CSV 17, respectively. The data showed that CSH 14 recorded maximum B: C ratio (2.95) which was significantly more over rest of the genotypes. Different genotypes have their genetic ability to produce higher yield resulted in higher net return and B: C ratio (Sumeriya and Singh, 2008; Dhaker, 2010) [3]. Application of 100% and 125% RDF provided significantly higher net return by 19.64 and 28.39 per cent over 75% RDF, respectively. However, 100% and 125% RDF were found statistically at par with each other. The application of 100% (2.47) and 125% RDF (2.53) provided significantly higher B: C ratio over 75% RDF but found at par with each other. This level recorded higher net return and B: C ratio due to the fact that this fertility level provided better nutritional environment resulted in higher productivity of grain as well as stover. It is obvious because grain and stover yield increased with the increase in the fertility levels in proportion to the cost of cultivation hence the net return and B: C ratio. Similar observations were also recorded by Patidar and Mali (2004), Kaushik and Shaktawat (2005) [9], Singh and Sumeriya (2006) [16], Dhaker (2010) [3].

Conclusion

On the basis of the results emanated from present investigation "Yield, nutrient content, nutrient uptake and economics of sorghum [Sorghum bicolor (L.) Moench] genotypes as affected by different fertility levels" conducted during kharif, 2016, it can be concluded that among genotypes CSH 14 found the best with respect to grain yield (4230 kg ha^{-1}), stover yield, nutrient content, nutrient uptake, net return (₹ 65266 ha^{-1}) and B: C ratio (2.95). Further, application of 125% RDF produced highest grain (3678 kg ha^{-1}), stover (12316 kg ha^{-1}) yield nutrient content and nutrient uptake. However, significant increase in net return (₹ 5483 ha^{-1}) and B: C ratio (2.47) was found with the application of 100% RDF.

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