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OPTIMIZATION OF RESOURCE IN FODDER SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH] UNDER SEMI-ARID CONDITIONS

SATPAL[1]*, B. GANGAIAH[2], S. DEVI[3], K. K. BHARDWAJ[4], A. KUMAR[5], P. KUMARI[1] AND NEELAM[6]

[1]Department of G & PB (Forage Section), [3]Department of Botany & Plant Physiology,
[4]Department of Soil Science, [5]Department of Agricultural Meteorology, [6]Department of Agronomy
CCS Haryana Agricultural University, Hisar-125 004 (Haryana), India
[2]ICAR - Indian Institute of Millets Research, Hyderabad-500 030 (Telangana), India
**(e-mail: satpal_fpj@hau.ac.in)*

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SUMMARY

Field experiments were conducted at Forage Section Research Farm, CCS HAU, Hisar for three *kharif* (rainy) seasons to quantify the impact of variety, fertilizer, weed control, plant protection, irrigation on single-cut forage sorghum total, per day productivity of fodder, fodder quality and finally economics. For this, performance of sorghum devoid of one of above input was compared with that receiving full package of practices (FPP). The study revealed that FPP contributed to 95.04% improvement in green fodder yields of single cut forage sorghum as compared to no FPP adopted (both for improved variety 'HJ 541') sorghum (28 t/ha). Exclusion of improved variety, weed control, plant protection, fertilizer and irrigation resulted in 39, 33, 31, 30, 22 per cent loss in the green fodder yield as compared to FPP (55 t/ha). Quality of fodder sorghum in terms crude protein (CP) and *in-vitro* dry matter digestibility (IVDMD) and NPK content improved and was at its best with adoption of FPP as compared to the exclusion of any of the input from FPP. Economics of single cut fodder sorghum revealed that net returns and benefit : cost (B:C) ratio were most impacted by the variety and use of local variety 'Duggi' resulted in 72.3 and 36 percent decrease in net returns and B:C ratio when compared to improved variety (Rs. 34938/ha and 2.03). From the study, it is concluded that improved variety as the most important basic requirement and input application to it is more rewardive than that given to a local variety. Further, seed treatment can be excluded from FPP without penalty on yield and returns in single cut forage sorghum cultivation.

Key words: Fodder yield, input management, fodder sorghum, crude protein, IVDMD, economics

Sorghum [*Sorghum bicolor* (L.) Moench], belonging to family Poaceae, is widely grown fodder crop of the country to support the green as well as dry fodder requirement of its livestock resources that stands at whopping 536.76 million (Anonymous, 2020). Sorghum that is cultivated for both fodder and grain purposes in arid and semi-arid regions is well known for its adaptability to harsh and variable climatic conditions not only in India but also in Africa. India with 5.4% (8.4 million ha) of the cultivated area under forage crops (Meena *et al.*, 2018) has a 14.1% deficiency in green fodder resources for livestock feeding (ICAR, 2026). Sorghum is a widely grown cereal forage crop with short duration along with ability to produce high biomass under wide edapho-climatic situations across the country including saline conditions (Satpal *et al.*, 2021). Since sorghum is a climate resilient crop, the present study was carried out to assess the impact of each input on growth, yield of forage sorghum and on quality of fodder in terms of crude protein (CP) content and *in-vitro* dry matter digestibility (IVDMD) under semi-arid region of Haryana state. In the absence of biotic and abiotic stresses, plant dry matter accumulation depends on the quantity of radiation absorbed by the canopy (Sinclair and Muchow, 1999). Satpal *et al.* (2020) also reported that varieties vary in their response to the inputs applied. The differential behavior of the two genotypes could be explained solely by the variation in their genetic constitution (Meena *et al.*, 2012). Keeping the above points in view, a field experiment was conducted to quantify the management component that had the greatest influence on growth, fodder yield, productivity, quality and economics of single cut forage sorghum, as compared to the full package of practices (FPP).

MATERIALS AND METHODS

The field experiment was conducted during *kharif* seasons of 2015, 2016 and 2017 at Forage Section Research Farm, CCS Haryana Agricultural University, Hisar (29° 10' N, 75° 46' E, at an average elevation of 215.2 m above mean sea level). Based on the three year mean soil analysis data (Table 1), the soil of the experimental site was sandy-loam in texture, slightly alkaline in reaction (pH 7.6), low in organic carbon (0.47%), low in available nitrogen (169.4 kg/ha), medium in available phosphorus (13.7 kg/ha) and high in available potassium (238.6 kg/ha). A rainfall of 229.7, 338.2 and 201.9 mm was received during 2015, 2016 and 2017 all treatments but during 2015, 209.9 mm rainfall was received for T_8 treatment. Weekly weather parameters *i.e.* temperature (°C), relative humidity (%) and rainfall (mm) during the crop duration are given Fig. 1, 2 and 3, respectively. The experiment consisted of eight treatments *viz.* T_1: Control (only improved cultivar 'HJ 541' without any input), T_2: Full package of practice (FPP) *i.e.* seed treatment + weed control + fertilizer + irrigation + plant protection + improved cultivar, T_3: FPP minus fertilizer, T_4: FPP minus weed control, T_5: FPP minus plant protection, T_6: FPP minus seed treatment, T_7: FPP minus irrigation and T_8: FPP minus improved variety (local cultivar 'Duggi'). The treatments were tested in randomized block design (RBD) with three replications. The sowing dates were 4th July 2015, 19th June 2016 and 18th July 2017, respectively. All the standard agronomic practices for the cultivation of forage sorghum were followed uniformly in all the treatments (Anonymous, 2013). A recommended fertilizer dose of 75-15 kg/ha N-P_2O_5 was used in FPP, out of which 50 kg N and full dose of phosphorus was applied basal and 25 kg N was top dressed in the form of urea at 30 days after sowing. Seed treatment was done with emisan @ 2g/kg seed to control the seed rot, grain smut and other seed borne fungal infections. For weed control, atrazine was applied @ 500 g *a.i.*/ha in 500 L of water as pre-emergence herbicide. Irrigation was applied as per the rainfall pattern and crop requirement. Two, one and two irrigations were applied during 2015, 2016 and 2017, respectively. For plant protection, one spray of carbaryl @ 500 g a.i./ha and one spray of malathion @ 625 ml a.i./ha was done to control stem borer (*Chilo partellus*) and grass hopper (*Hieroglyphus banian*), respectively.

The samples for estimation of HCN (hydrocyanic acid) were taken at 30 DAS from the portion of the plant immediately below the uppermost leaf collar and HCN content was estimated as per Hogg and Ahlgren (1942). The amount of HCN (µg/g) was calculated on fresh weight basis with the help of standard curve. For standard curve, different concentration of KCN were taken and absorbance at 515 nm was recorded using spectrophotometer. Total nitrogen content was estimated in dried and grinded samples (2 mm sieve size) collected at 50 per cent flowering stage according to the conventional micro-kjeldal method (AOAC, 1995). The crude protein (CP) content was based on total nitrogen (N) multiplied by 6.25. *In-vitro* dry matter digestibility (IVDMD) was estimated by method of Barnes *et al.* (1971). Phosphorus was determined by the vanado-molybdo-phosphoric yellow color method as described by Koenig and Johnson (1942), while potassium content was estimated using the flame photometric method described by Richards (1954). Data were analyzed by using OPSTAT software available at CCS Haryana Agricultural University website (Sheoran *et al.*, 1998). The results are presented at five per cent level of significance (p=0.05) for making comparison between treatments.

TABLE 1
Initial properties of soil before sowing of the experiment

S. No.	Particulars	Results			
		2015	2016	2017	Mean
1.	Soil texture	Sandy loam	Sandy loam	Sandy loam	Sandy loam
2.	Soil pH	7.5	7.5	7.7	7.6
3.	EC (dS/m)	0.26	0.35	0.42	0.34
4.	OC (%)	0.36	0.54	0.52	0.47
5.	Available N (kg/ha)	171.4	182.0	154.8	169.4
6.	Available P (kg/ha)	13.1	16.0	12.0	13.7
7.	Available K (kg/ha)	215.7	252.0	248.0	238.6

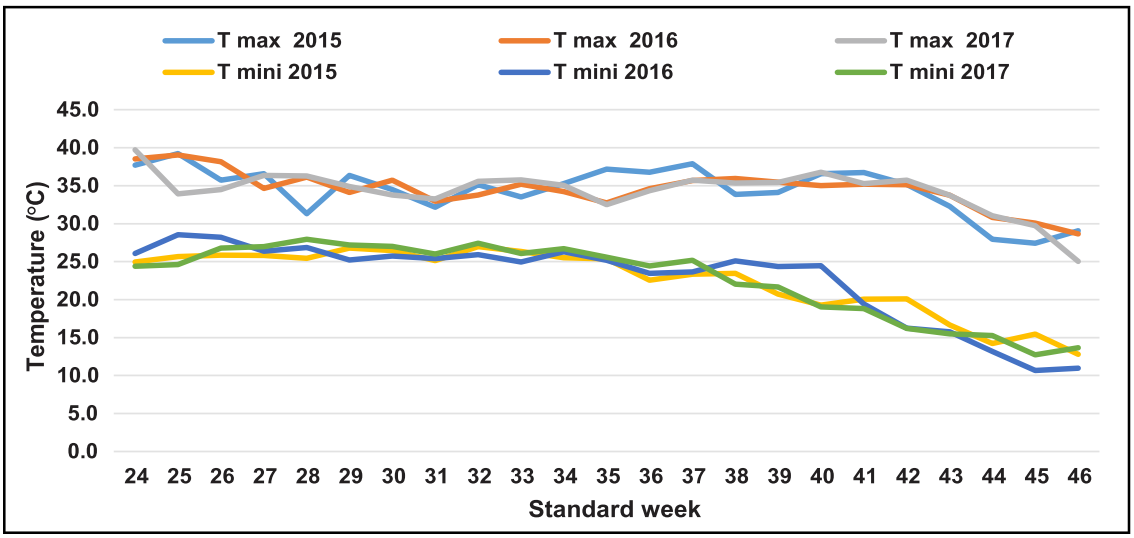

Fig. 1. Temperature during *kharif* 2015 to 2017.

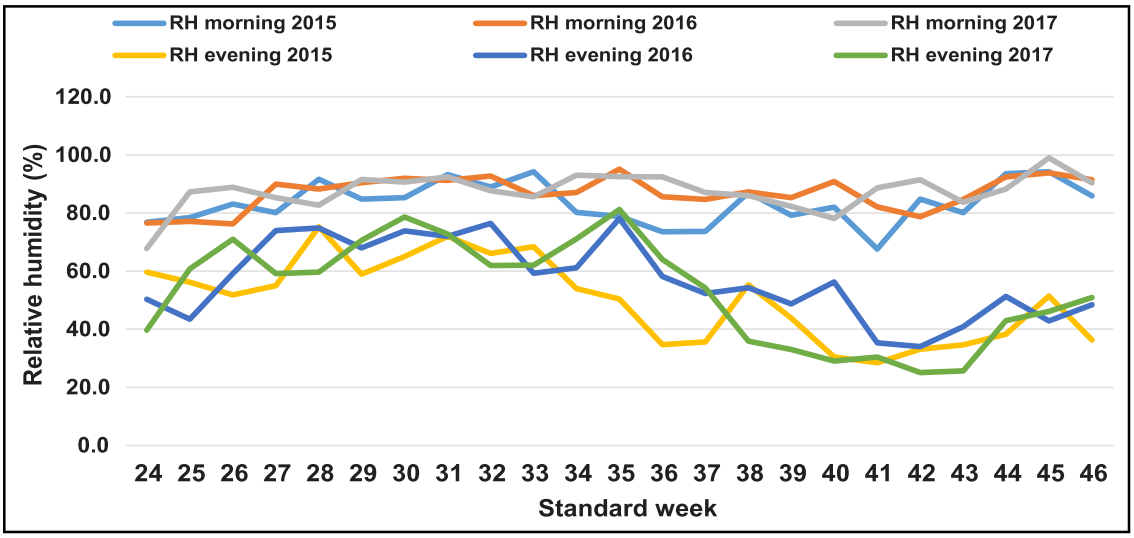

Fig. 2. Relative humidity during *kharif* 2015 to 2017.

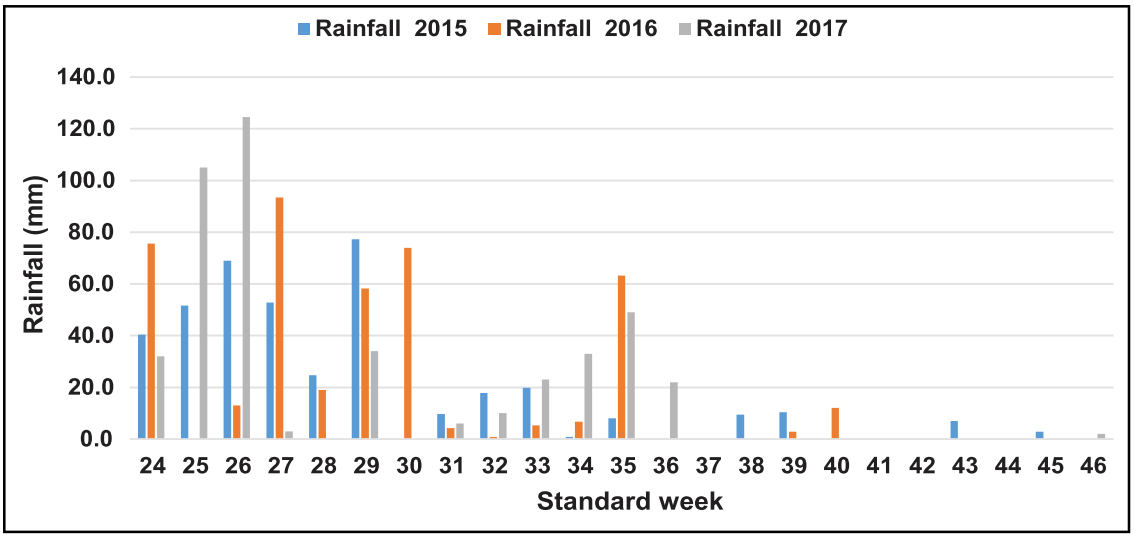

Fig. 3. Rainfall during *kharif* 2015 to 2017.

TABLE 2
Relative impact of production inputs on the growth, yield attributes, yield and productivity of single-cut forage sorghum (Three year mean data)

Treatment	Plant height (cm) at harvest	Leaf area index (LAI)	Leaf to stem ratio (L:S)	Days to 50% flowering	Green fodder yield (t/ha)	Dry matter yield (t/ha)	Per day productivity (kg/day/ha)	
							Green fodder	Dry matter
T_1: Control	191.5	3.10	0.17	93	28.2	7.1	303.1	75.7
T_2: FPP	262.9	5.19	0.27	94	55.0	14.2	583.7	150.7
T_3: FPP - Fertilizer	213.4	3.98	0.19	97	38.5	9.4	393.9	96.6
T_4: FPP - Weed control	207.0	3.79	0.17	94	36.9	9.3	391.6	99.0
T_5: FPP - Plant protection	209.1	3.79	0.17	93	37.9	9.7	404.7	103.6
T_6: FPP - Seed treatment	261.5	5.16	0.26	96	53.7	13.8	556.3	143.1
T_7: FPP - Irrigation	214.5	4.30	0.19	94	42.9	10.7	455.8	114.2
T_8: FPP - Improved variety	221.2	3.48	0.20	79	33.7	8.0	425.8	101.3
SEm±	7.27	0.190	0.009	0.8	1.59	0.42	18.07	4.98
C.D. (p=0.05)	22.26	0.582	0.027	2.4	4.83	1.28	54.82	15.10

RESULTS AND DISCUSSION

Crop growth and yield

Management practices in terms of input supply has significantly influenced the growth and yield of fodder sorghum. Three year mean data presented in Table 2 revealed that among the management practices, fodder sorghum crop receiving FPP being on a par with FPP minus seed treatment has produced significantly taller plants (262.9 cm), leaf area index (5.19) and leaf to stem ratio (0.27) than rest of the treatments. Exclusion of fertilizer application from FPP (T_3) being at par with FPP minus seed treatment has resulted in significant delay in days to 50% flowering (97) over rest of the treatments. Delayed flowering in sorghum under fertilizer omission is primarily associated with nutrient deficiencies, especially nitrogen (N), phosphorus (P), and, to a lesser extent, potassium (K). These nutrients regulate vegetative growth, photosynthesis, assimilate production, and reproductive development. When fertilizers are excluded, nutrient stress prolongs the vegetative phase and delays the transition to reproductive growth. Blandino *et al*. (2022) reported earlier flowering with starter fertilizer dose (rich in phosphorus and nitrogen) application at sowing due to enhanced early root development. Local cultivar 'Duggi' (79) took least number of days to attain 50% flowering stage as compared to improved variety used with FPP (94 days). Short duration of local cultivar 'Duggi' is the reason for its wider adoption by farmers even though it has low yields. Improved variety (HJ 541) has 38.7 per cent higher green fodder yield than local cultivar 'Duggi' (33.7 t/ha) when both grown with FPP. The differential behavior of the two genotypes could be explained solely by the variation in their genetic constitution (Meena *et al*., 2012). Plants have a definite heat requirement before they attain certain phenophases. A change in temperature during phenophases of a crop adversely affects the initiation and duration of different phenophases and finally the economic yield (Prakash *et al*., 2017).

Data presented in Table 2 and Fig. 4 revealed that significantly higher green fodder and dry matter yields (55.0 and 14.2 t/ha) were recorded by fodder sorghum cultivated FPP over all other treatments except FPP minus seed treatment. The reduction in GFY was maximum due to use of local cultivar (T_8) with FPP was followed by 30-35 per cent reduction with the fertilizer, weed control and plant protection excluded treatments from FPP. The reduction in green fodder yield was least (22%) due to exclusion of irrigation from FPP. This was ascribed to the adequate soil moisture maintenance by virtue of received rainfall during the *kharif* seasons. The reduction in GFY due to exclusion of all the improved inputs *i.e.* FPP for improved cultivar was 48.73%. The reduction in GFY was 39% in the exclusion of improved cultivar, 30 to 33% in the exclusion of fertilizer, weed control and plant protection each and 22% in the irrigation excluded treatment, respectively. Fig. 5 represent DMY which followed the same trend as of GFY.

Data presented in Table 2 reveal that FPP being at par with FPP minus seed treatment has recorded significantly higher per day productivity of

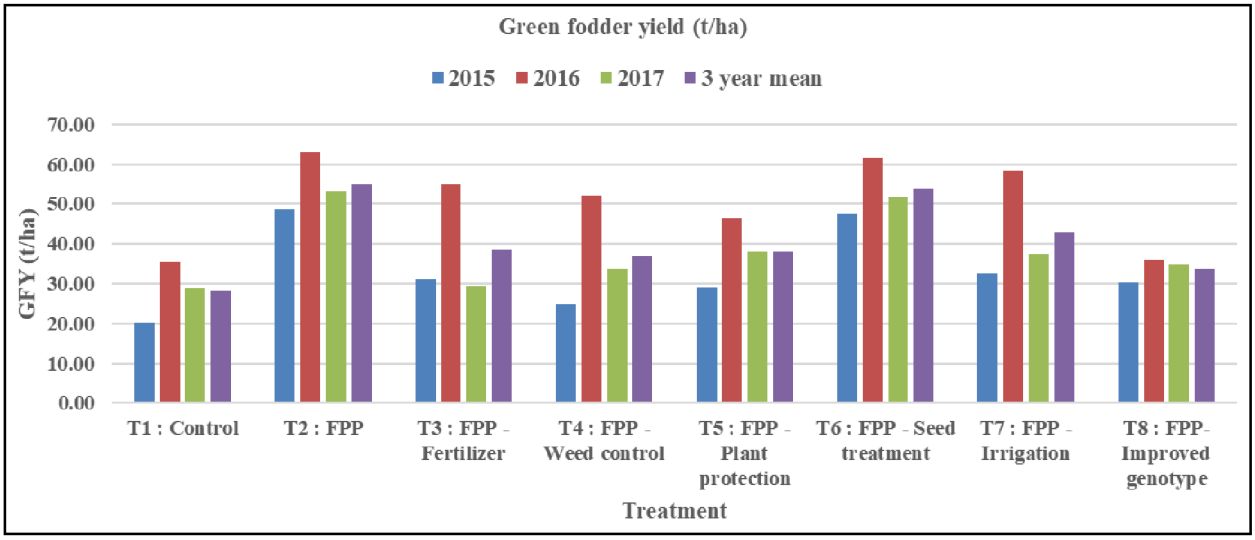

Fig. 4. Green fodder yield of single cut fodder sorghum under different input exclusion treatments.

green fodder and dry matter (583.7 and 150.7 kg/ha/day) than rest of the treatments. Exclusion of improved variety, weed control, plant protection, fertilizer and irrigation from FPP resulted in 27, 33, 31, 33 and 22 per cent loss, respectively, in the per day productivity of green fodder as compared to FPP.

Quality

Data presented in Table 3 reveal that FPP being at par with FPP minus seed treatment has recorded significantly higher crude protein (CP) content (9.56%) and IVDMD (52.73%) values than rest of the treatments. Further, the IVDMD values recorded by FPP was at a par with FPP minus weed control and, FPP minus plant protection. All the inputs (improve variety, fertilizer and irrigation, etc.) contribute towards growth and quality of sorghum. Crude protein content and IVDMD of fodder sorghum improved with fertilizer application (Oberoi *et al.*, 2020). Satpal *et al.* (2026) also reported a 29 and 11 per cent increase in CP and IVDMD content of single cut fodder sorghum with recommended fertilizer dose application over no fertilizer application. On fresh weight basis, the HCN content remained below critical limit (200 µg/g at 30 days) in all the treatments. Although the estimated HCN content of FPP - Improved variety (Duggi – a local cultivar) was significantly higher (111.3 µg/g) over other FPP excluding any single input or with full FPP. NPK content in the fodder was also significantly influenced by the productions factors. Highest NPK content (1.53, 1.19 and 1.26%) was estimated in FPP treatment which were on a par with all the other treatments except FPP minus seed treatment for N content. For P content, FPP was on a par with FPP- minus seed

TABLE 3
Relative impact of production inputs on quality of single-cut sorghum (three year mean data)

Treatment	HCN at 30 DAS (µg/g)	Crude protein (%)	IVDMD (%)	Nutrient content (%)		
				N	P	K
T_1: Control	52.5	8.24	50.37	1.32	0.15	1.16
T_2: FPP	94.3	9.56	52.73	1.53	0.19	1.26
T_3: FPP - Fertilizer	65.2	8.22	49.07	1.31	0.17	1.23
T_4: FPP - Weed control	55.3	8.39	50.67	1.34	0.18	1.21
T_5: FPP - Plant protection	101.0	8.18	51.50	1.31	0.19	1.25
T_6: FPP - Seed treatment	77.5	9.20	52.37	1.47	0.19	1.25
T_7: FPP - Irrigation	73.6	8.32	49.40	1.33	0.18	1.23
T_8: FPP - Improved variety	111.3	7.99	49.27	1.28	0.17	1.21
SEm±	1.87	0.144	0.713	0.023	0.002	0.02
C.D. (p=0.05)	5.73	0.440	2.180	0.070	0.007	0.055

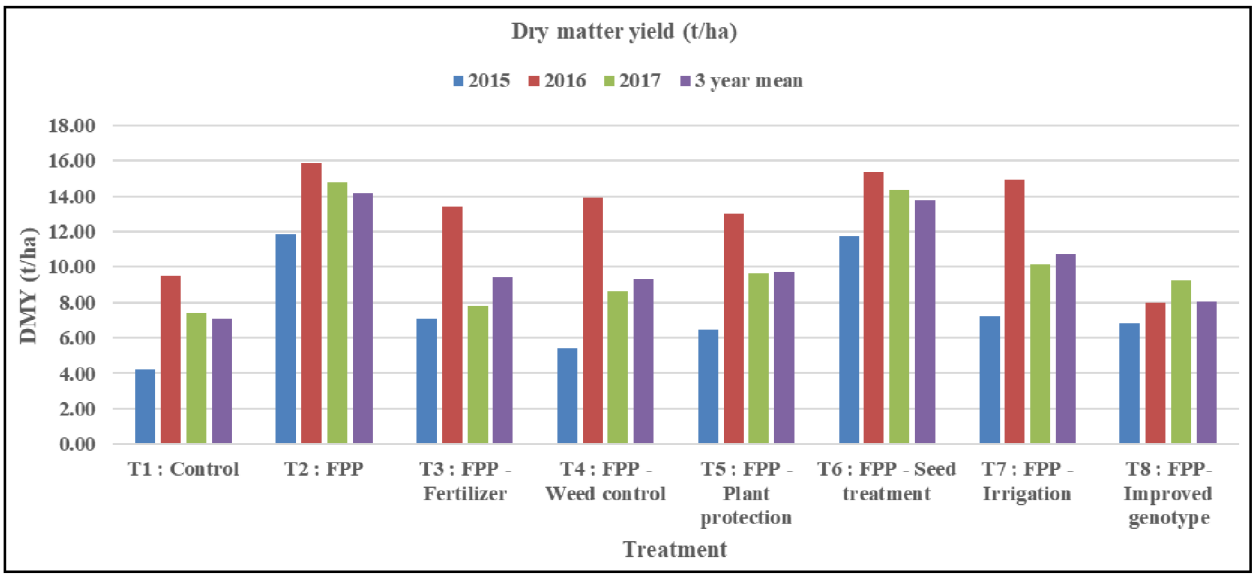

Fig. 5. Dry matter yield of single cut fodder sorghum under different input exclusion treatments.

TABLE 4
Economics of single-cut forage sorghum cultivation as influenced by production inputs (3 year mean data)

Treatment	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	BC ratio
T_1: Control	24402	35299	10896	1.49
T_2: FPP	33833	68771	34938	2.03
T_3: FPP - Fertilizer	32160	48111	15951	1.50
T_4: FPP - Weed control	28754	46081	17326	1.65
T_5: FPP - Plant protection	33019	47361	14342	1.43
T_6: FPP - Seed treatment	33595	67150	33555	2.00
T_7: FPP - Irrigation	32141	53597	21456	1.66
T_8: FPP - Improved variety	32412	42107	9695	1.30
SEm±	-	1989.2	1989.1	0.066
C.D. (p=0.05)	-	6092.0	6091.8	0.203

treatment, FPP- Plant protection and FPP- Improved variety. But the K content of FPP was on a par with all the treatments except control where no input was applied.

ECONOMICS

Data presented in Table 4 reveal that FPP being at par with FPP excluding seed treatment or irrigation has resulted in significantly higher net returns and benefit cost ratio (34938 and 2.03, respectively) than rest of the treatments. Benefit cost ratio (B:C) of single cut fodder sorghum was most affected by the variety as evident from 36% lower values with local variety when compared to of improved variety both cultivated with FPP.

CONCLUSION

From the three years' study, it is concluded that management practices contributed to 95.04% improvements in green fodder yield of single cut forage sorghum (HJ 541). Among the inputs, absence of improved variety (27%), weed control (33%), plant protection (31%) and fertilizer (33%), irrigation (22%) resulted in the per day productivity loss of green fodder as compared to FPP. Quality of fodder sorghum improved with FPP as compared to the absence of any other input. Benefit cost ratio (B:C) of single cut fodder sorghum was most affected (36% decrease) in the absence of improved variety compared to FPP.

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