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Yield and Harvest Index of Grain Sorghum as Influenced by Agronomic Practices under Summer Rice Fallow in Southern Kerala, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A study was undertaken at College of Agriculture, Vellayani, during January 2024 to May 2024 to standardize tillage, plant population and nutrient management practices for grain sorghum under summer rice fallows. The experiment was laid out in RCBD with 2 x 2 x 3 treatments, replicated thrice and the treatments comprised of combinations of two tillage methods (T_1-zero tillage, T_2-conventional tillage), two levels of spacing (P_1 – 45 x 15 cm, P_2- 60 x 15 cm) and three NPK levels (N_1 – 45:25:25 NPK kg ha^{-1}, N_2 – 50:25:75 NPK kg ha^{-1} and N_3 – 50:25:50 NPK kg ha^{-1}). Among yield attributes, sorghum grown under zero tillage with a spacing 45 x 15 cm and a nutrient dose of 50:25:50 NPK kg ha^{-1} ($T_1P_1N_3$) resulted in higher panicle length (22.70 cm), number of grains per

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panicle (1836.67) and grain weight per panicle (35.96 g). Higher grain yield (5.14 t ha^{-1}) was obtained in treatment $T_1P_1N_3$, which was found on par with $T_1P_1N_2$ (4.96 t ha^{-1}) and higher stover yield (8.10 t ha^{-1}) was obtained in treatment $T_1P_1N_2$, which was found on par with $T_1P_1N_3$ (7.81 tha^{-1}). Harvest index was higher in treatment $T_2P_2N_1$ (0.43) and remained comparable with $T_1P_1N_3$ (0.40) and $T_1P_1N_2$ (0.39).

Keywords: Sorghum; summer rice fallows; zero tillage; conservation tillage; harvest index.

1. INTRODUCTION

Sorghum is a versatile crop, renowned for its adaptability to various cropping systems and harsh environmental conditions, typically of semi-arid regions. Sorghum can withstand both drought and excessive soil moisture so called crop camel. The C4 photosynthesis pathway, deep root system and its quick-growing habit allows it to survive on marginal lands, making sorghum a climate-resilient and drought tolerant crop. Paddy fallows basically imply to those lowland kharif rice areas, which remain uncropped during rabi season. In South Asia, India accounts for the majority, approximately 79 per cent, of total rice fallow area, which amounts to around 11.65 million hectares out of total 15.0 million hectares in the region. Sorghum in rice fallows is gaining popularity among the farmers and the crop is exclusively cultivated in rice fallows under zero tillage condition (Mishra and Chapke, 2016). Sowing of crops under zero-tillage has many economic and environmental benefits over conventional tillage, such as lower labour and fuel needs, reduced soil erosion, reduced run off, increased soil organic C contents, and increased soil biological activity. In rice fallows, after the harvest of kharif transplanted rice, sorghum is sown in second fortnight of December to January under zero-tillage on the residual soil moisture (Chapke and Babu, 2016).Changing plant population density is one of the strategies to promote more effective water consumption. Closer rows and higher plant density result in more efficient use of solar radiation, nutrients and water resources (McGowan et al., 1991). The yield of grain sorghum can be improved by increasing the plant densities (Zand et al., 2013).

Sorghum responds well to nutrient application, with higher yields being achieved through a balanced application of NPK. In rice- fallows of Andhra Pradesh, farmers were applying higher dose of fertilizers (150-200 kg N, 75-80 kg P_2O, and 75 kg K_2O per ha) (Chapke and Babu^o, 2016). For rainfed sorghum cultivation in Kerala, NPK recommendation is 45:25:25 kg ha^{-1} (KAU, 2016). However, Karthik (2021) reported a modified fertilizer dose of 50:25:75 kg ha^{-1} NPK with N and K in two equal split doses, half of each at basal and at 30DAS and P as basal dose for cultivating high yielding sorghum varieties as rainfed crop in southern Kerala (Karthik, 2021). Shrotriya (1998) reported that balanced application of NPK resulted in an increase in sorghum yield up to 122 per cent under Indian conditions. Hence, the present study was undertaken at College of Agriculture, Vellayani, during January 2024 to May 2024 to standardize tillage, plant population and nutrient management for grain sorghum under summer rice fallows.

2. MATERIALS AND METHODS

2.1 Location of Study

The experiment was conducted in wetlands of Instructional farm, College of Agriculture, Vellayani, Thiruvananthapuram. The experimental field is located at 8^o 25' 47" N latitude and 76^o 59' 04" E longitude at an altitude of 24.15 m above mean sea level. The soil was sandy clay loam with strong acidity (pH), safe electrical conductivity (EC) and high organic carbon content (OC). The soil was medium in available nitrogen and high in available phosphorus and low in available potassium. The experiment was conducted during summer 2024. The mean maximum temperature ranged between 34.4^0 C and 32.2^0 C and mean minimum temperature ranged between 25.8^0 C and 20.0^0 C, mean maximum relative humidity ranged between 94.40 per cent and 85.14 per cent, and mean minimum relative humidity ranged between 76.10 per cent and 64.42 per cent. A total rainfall of 343.20 mm was received during the cropping period.

2.2 Treatments

The experiment was laid out in RCBD with 2 x 2 x 3 treatments, replicated thrice. The treatments comprised combinations of two tillage methods (T_1-zero tillage, T_2-conventional tillage), two levels of spacing (P_1 – 45 x 15 cm, P_2- 60 x 15 cm) and three levels of NPK (N_1 – 45:25:25 NPK kg ha^{-1}, N_2 – 50:25:75 NPK kg ha^{-1} and N_3 – 50:25:50 NPK kg ha^{-1}). The weeds in the experimental plots were cleared using brush cutter. Bunds were created to divide the experimental area into individual plots. Plots of 4.5 m × 4.5 m were prepared with 30 cm wide bunds on all four sides. Then plots with conventional tillage treatment was ploughed and the clods were crushed, levelled and brought to a fine tilth and plots with zero tillage treatment was left as such. The sorghum variety used for the study was CO-32. Farmyard manure was applied @ 5 t ha^{-1} at the time of land preparation. Nitrogen was applied @ 45 kg ha^{-1} and 50 kg ha^{-1} as urea to the plots according to the dose and as per the time of application of treatments. Potassium was applied @ 25 kg ha^{-1}, 50 kg ha^{-1} and 75 kg ha^{-1} to the plots according to the dose and as per the time of application of treatments as muriate of potash. The entire quantity of phosphorus @ 25 kg ha^{-1} was applied as a basal dose.

2.3 Observations

Observations were taken on yield attributes *viz*., length of panicle, number of grains per panicle, grain weight per panicle, test weight, grain yield, stover yield and harvest index. Five observational plants were selected at random and tagged in each plot, and observations were recorded from these plants. After the harvest, panicle length was measured from the base of the panicle to its tip and expressed in cm. From the sample plants in each plot, grains from each panicle were removed and counted, and the mean value was calculated. The grains removed from sample panicles were weighed using an electronic balance. The mean value was calculated and expressed in g per panicle as grain weight per panicle. One thousand fully filled, bold grains were taken and weighed separately from each plot. The mean value was calculated and expressed in grams (g) as test weight. The panicles harvested from each plot were threshed separately, and grains were separated, sun-dried, cleaned, and weighed to calculate the grain yield. The values were recorded and expressed in t ha^{-1}. After the harvest completed green stover was cut at ground level from each plot. They were shade dried and then oven dried at 65 ± 5°C until a constant weight was achieved and the weight of stover was expressed in t ha^{-1}. Harvest index (HI) was calculated using the formula suggested by Donald and Hamblin (1976).

$$HI = \frac{Economic\ yield}{Biological\ yield} \times 100$$

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

Length of panicle: Sorghum grown under zero tillage with 45 cmx 15 cm spacing and a nutrient dose of 50:25:50 kg NPK ha^{-1}($T_1P_1N_3$) produced highest length of panicle (22.70 cm), which was on par with all other treatments ($T_1P_2N_2$- 22.57 cm, $T_2P_2N_3$ - 22.54 cm, $T_1P_2N_1$ - 21.59 cm, $T_2P_1N_3$- 21.37 cm, $T_1P_1N_2$- 21.20 cm, $T_1P_1N_1$- 21.18 cm, $T_2P_1N_2$- 20.49 cm, $T_2P_2N_1$- 20.33 cm, $T_1P_2N_3$- 20.27 cm and $T_2P_1N_1$- 20.26 cm) except $T_2P_2N_2$ (19.26 cm)(Table 1c).The main effects and T × P, T × N and P × N interaction effects could not significantly influence the length of panicle (Table 1a, Table 1b).

Number of grains per panicle: Sorghum grown under zero tillage and at 45 cm x 15 cm spacing (T_1P_1) produced the highest number of grains per panicle (1585.22), which was on par with T_2P_2 (1480.44) (Table 1b). Sorghum grown under zero tillage and with 50:25:50 kg NPK ha^{-1} produced the highest number of grains per panicle (1577.17), which was on par with treatments T_2N_1 (1473.33), T_2N_2 (1451.50) and T_1N_2 (1426.00) (Table 1b). Sorghum grown under 45 cm x 15 cm spacing and with 50:25:50 kg NPK ha^{-1} nutrient dose produced highest number of grains per panicle (1685.00), which was on par with P_2N_1 (1533.33) (Table 1b). Sorghum grown under zero tillage with 45 cm x 15 cm spacing and with 50:25:50 kg NPK ha^{-1} produced highest number of grains per panicle (1836.67) (Table 1c). The main effects could not significantly influence the number of grains per panicle (Table 1a).

Grain weight per panicle: Results shows that sorghum under zero tillage (T_1) produced the highest grain weight per panicle (27.02 g). Sorghum with a spacing of 45 cm x 15 cm (P_1) resulted in highest grain weight per panicle of (26.70 g). Also, a nutrient dose of 50:25:50 kg NPK ha^{-1} (N_3) resulted in highest grain weight per panicle (26.30 g) followed by N_2 (50:25:75 kg NPK $ha^{-1)}$ with grain weight per panicle (26.29), which were on par each other (Table 1a). First order interaction effects shows that sorghum under zero tillage with 45 cm x 15 cm spacing

(T_1P_1) produced the highest grain weight per panicle (27.73 g), which was on par to all other treatments (T_2P_2- 27.08 g, T_1P_2- 26.32 g) except T_2P_1 (17.24). Sorghum grown under zero tillage with 50:25:75 kg NPK ha^{-1} (T_1N_2) produced the highest grain weight per panicle (31.63 g) followed by T_1N_3 (31.14 g) which were on par each other. Sorghum grown with 45 cm x 15 cm spacing and 50:25:50 kg NPK ha^{-1} (P_1 N_3) produced highest grain weight per panicle (29.12 g), which was on par with P_2N_1 (28.52 g) and P_2N_2 (28.09 g) (Table 1b).

Table 1a. Effect of tillage, spacing and nutrient management on yield attributes of sorghum

Treatments	Length of panicle(cm)	No of grains per panicle	Grain weight per panicle(g)	Test weight(g)
Tillage (T)				
T_1 (Zero tillage)	21.58	1462.78	27.02	25.19
T_2 (Conventional tillage)	20.71	1412.28	22.16	25.32
SEm (±)	0.34	32.30	0.52	0.19
CD (p = 0.05)	NS	NS	1.54	NS
Spacing (P)				
P_1 (45 x 15 cm)	21.20	1464.67	22.48	25.22
P_2 (60 x 15 cm)	21.09	1410.39	26.70	25.29
Seem (±)	0.34	32.30	0.52	0.19
CD (p = 0.05)	NS	NS	1.539	NS
Nutrient management(N)				
N_1 (45:25:25 NPK kg ha^{-1})	20.84	1429.25	21.18	25.28
N_2 (50:25:75 NPK kg ha^{-1})	20.88	1438.75	26.29	25.26
N_3 (50:25:50 NPK kg ha^{-1})	21.72	1444.58	26.30	25.22
SEm (±)	0.42	39.56	0.64	0.23
CD (0.05)	NS	NS	1.884	NS

Table 1b. Interaction effects of tillage, spacing and nutrient management on yield attributes of sorghum

Interactions	Length of panicle(cm)	No of grains per panicle	Grain weight per panicle(g)	Test weight(g)
Tillage (T) x Spacing (P)				
T_1P_1	21.69	1585.22	27.73	25.26
T_1P_2	21.47	1340.33	26.32	25.11
T_2P_1	20.70	1344.11	17.24	25.17
T_2P_2	20.71	1480.44	27.08	25.48
SEm (±)	0.48	45.68	0.74	0.26
CD (p= 0.05)	NS	133.968	2.176	NS
Tillage (T) x NPK Levels (N)				
T_1N_1	21.38	1385.17	18.29	25.18
T_1N_2	21.88	1426.00	31.63	25.28
T_1N_3	21.48	1577.17	31.14	25.09
T_2N_1	20.29	1473.33	24.07	25.38
T_2N_2	19.87	1451.50	20.95	25.23
T_2N_3	21.96	1312.00	21.46	25.35
SEm (±)	0.59	55.94	0.91	0.32
CD (p= 0.05)	NS	164.077	2.665	NS
Spacing (P) x NPK Levels (N)				
P_1N_1	20.72	1325.17	13.84	25.30
P_1N_2	20.84	1383.83	24.50	25.22
P_1N_3	22.03	1685.00	29.12	25.13
P_2N_1	20.96	1533.33	28.52	25.27
P_2N_2	20.91	1493.67	28.09	25.30
P_2N_3	21.41	1204.17	23.49	25.31
SEm (±)	0.59	55.94	0.91	0.32
CD (p= 0.05)	NS	164.077	2.665	NS

Sorghum grown under zero tillage with 45 cm x 15 cm spacing and 50:25:50 kg NPK ha^{-1}(T_1P_1 N_3) recorded higher grain weight per panicle (35.96 g), which was found on par with T_1P_1 N_2 (33.53 g) (Table 1c). The reduced disturbance of soil structure under zero tillage promotes better nutrient retention and availability, which can positively affect grain weight per panicle (Laxmi, et al., 2007). Closer spacing may lead to better canopy coverage, which enhances light interception and photosynthesis (Wang et al., 2023). Research consistently shows that increased nitrogen application improves sorghum yield and grain quality. Higher nitrogen levels (up to 120 kg N ha^{-1}) significantly increased grain weight per panicle across various sorghum genotypes (Kumar et al., 2012).

Test weight: Tillage, spacing, nutrient management could not significantly effect the test weight of sorghum grown during summer rice fallows (Table 1a, 1b and 1c).

3.2 Yield

Tillage, spacing and nutrient management significantly effect the grain yield, stover yield and harvest index of sorghum.

Table 1c. Effect of T X P X N interaction on yield attributes of sorghum

Treatment combinations	Length of panicle(cm)	No of grains per panicle	Grain weight per panicle(g)	Test weight(g)
Tillage (T) X Spacing (P) x NPK Levels (N)				
$T_1P_1N_1$	21.18	1577.00	13.69	25.29
$T_1P_1N_2$	21.20	1601.32	33.53	25.57
$T_1P_1N_3$	22.70	1836.67	35.96	24.93
$T_1P_2N_1$	21.59	1193.33	22.89	25.07
$T_1P_2N_2$	22.57	1510.00	29.73	25.00
$T_1P_2N_3$	20.27	1317.67	28.33	25.25
$T_2P_1N_1$	20.26	1073.33	13.99	25.30
$T_2P_1N_2$	20.49	1425.67	15.46	24.87
$T_2P_1N_3$	21.37	1533.33	22.29	25.33
$T_2P_2N_1$	20.33	1587.78	24.15	25.47
$T_2P_2N_2$	19.26	1477.33	26.44	25.60
$T_2P_2N_3$	22.54	1090.67	20.64	25.37
SEm (±)	0.84	79.12	1.28	0.46
CD (p=0.05)	2.448	232.04	3.175	NS

Table 2a. Effect of tillage, spacing and nutrient management on grain yield, stover yield and harvest index of sorghum

Treatments	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Tillage (T)			
T_1 (Zero tillage)	3.28	6.48	0.33
T_2 (Conventional tillage)	2.42	5.51	0.31
SEm (±)	0.06	0.10	0.007
CD (p=0.05)	0.172	0.283	0.019
Spacing (P)			
P_1 (45 x 15 cm)	3.08	6.52	0.31
P_2 (60 x 15 cm)	2.62	5.46	0.34
SEm (±)	0.06	0.10	0.007
CD (p=0.05)	0.172	0.283	NS
Nutrient management (N)			
N_1 (45:25:25 NPK kg ha^{-1})	2.27	5.17	0.32
N_2 (50:25:75 NPK kg ha^{-1})	3.13	7.09	0.30
N_3 (50:25:50 NPK kg ha^{-1})	3.15	5.72	0.36
SEm (±)	0.07	0.12	0.008
CD (p=0.05)	0.21	0.346	0.023

Grain yield: Sorghum under zero tillage (T_1) produced the highest grain yield (3.28 t ha^{-1}). Sorghum grown under 45 cm x 15 cm spacing (P_1) resulted in highest grain yield (3.08 t ha^{-1}). Also, N_3 (50:25:50 kg NPK ha^{-1}) resulted in highest grain yield (3.15 t ha^{-1}) followed by N_2 (50:25:75 kg NPK $ha^{-1)}$ with grain yield of 3.13 t ha^{-1}, which were on par each other (Table 2a). Sorghum grown under zero tillage with 45 cm x 15 cm spacing (T_1P_1) produced the highest grain yield (3.96 t ha^{-1}). Sorghum grown under zero tillage with 50:25:75 kg NPK ha^{-1} (T_1N_2) produced the highest grain yield (4.00 t ha^{-1}), followed by T_1N_3 (3.84 t ha^{-1}) which were on par each other. Sorghum grown with 45 cm x 15 cm spacing and 50:25:50 kg NPK ha^{-1} nutrient dose (P_1N_3) produced highest grain yield (3.99 t ha^{-1}) (Table 2b).

Sorghum grown under zero tillage under 45 cm x 15 cm spacing and with 50:25:50 kg NPK ha^{-1} ($T_1P_1N_3$) resulted in higher grainyield (5.14 t ha^{-1}), which was on par with $T_1P_1N_2$ (4.96 t ha^{-1}) (Table 2c). The improvement in yield is attributed to several factors, including better soil moisture retention, timely planting, and reduced soil disturbance. This leads to enhanced yield components as a result of water conservation, better surface residue management, improved soil biological activity, and improved soil structure (Busari et al., 2015). Closer spacing improve water use efficiency by reducing evaporation from soil surface and ensuring more water availability to plants (Ngidi et al., 2024) and also closer spacing can suppress weed growth by shading soil surface, reducing competition for resources and allowing sorghum plants to thrive (Nagesh et al., 2022). Potassium is crucial for promoting optimal plant growth. Activates numerous essential enzymes involved in processes like protein synthesis, sugar transport, N and C metabolism, and photosynthesis thus significantly contributes to improve crop yield (Marschner et al., 2011).

Stover yield: Sorghum under zero tillage (T_1) produced the highest stover yield (6.48 t ha^{-1}). Sorghum grown with 45 cm x 15 cm spacing (P_1) resulted in highest stover yield (6.52 t ha^{-1}). Also, N_2 (50:25:75 kg NPK ha^{-1}) resulted in highest stover yield (7.09 t ha^{-1}) followed by N_3 (50:25:50 kg NPK $ha^{-1)}$ with stover yield of 5.72 t ha^{-1} (Table 2a). Sorghum grown under zero tillage with 45 cm x 15 cm spacing (T_1P_1) produced the highest stover yield (7.27 t ha^{-1}). Sorghum grown under zero tillage with 50:25:75 kg NPK ha^{-1} nutrient dose (T_1N_2) produced the highest stover yield (7.99 t ha^{-1}) followed by T_1N_3 (6.28 t ha^{-1}). Sorghum grown with 45 cm x 15 cm spacing and 50:25:75 kg NPK ha^{-1} nutrient dose (P_1 N_2) produced highest stover yield (7.34 t ha^{-1}) which was on par with P_1 N_3 (6.85 t ha^{-1}) (Table 2b). Sorghum grown under zero tillage with 45 cm x 15 cm spacing and a nutrient dose of 50:25:75 kg NPK ha^{-1} (T_1P_1 N_2) resulted in higher stoveryield (8.10 t ha^{-1}) which was on par with treatment $T_1P_2N_2$ (7.88 t ha^{-1}) and T_1P_1 N_3 (7.81 t ha^{-1}) (Table 2c).

Table 2b. Interaction effects of tillage, spacing and nutrient management on grain yield, stover yield and harvest index of sorghum

Interactions	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Tillage (T) x Spacing (P)			
T_1P_1	3.96	7.27	0.34
T_1P_2	2.60	5.69	0.33
T_2P_1	2.20	5.78	0.27
T_2P_2	2.65	5.23	0.35
SEm (±)	0.08	0.14	0.009
CD (0.05)	0.243	0.40	0.027
Tillage (T) x NPK Levels (N)			
T_1N_1	1.98	5.16	0.28
T_1N_2	4.00	7.99	0.33
T_1N_3	3.84	6.28	0.39
T_2N_1	2.55	5.18	0.35
T_2N_2	2.25	6.18	0.27
T_2N_3	2.46	5.16	0.32
SEm (±)	0.10	0.17	0.01
CD (0.05)	0.297	0.489	0.03
Spacing (P) x NPK Levels (N)			
P_1 N_1	1.77	5.38	0.25
P_1 N_2	3.45	7.34	0.30
P_1 N_3	3.99	6.85	0.36

Interactions	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
P_2N_1	2.76	4.96	0.38
P_2N_2	2.80	6.84	0.29
P_2N_3	2.30	4.58	0.35
SEm (±)	0.10	0.17	0.01
CD(0.05)	0.297	0.489	0.03

Table 2c. Effect of T X P X N interaction on grain yield, stover yield and harvest index of sorghum

Treatment combination	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index
Tillage(T) X Spacing(P) x NPK Levels(N)			
$T_1P_1N_1$	1.77	5.90	0.23
$T_1P_1N_2$	4.96	8.10	0.39
$T_1P_1N_3$	5.14	7.81	0.40
$T_1P_2N_1$	2.20	4.43	0.33
$T_1P_2N_2$	3.05	7.88	0.28
$T_1P_2N_3$	2.55	4.76	0.38
$T_2P_1N_1$	1.78	4.87	0.27
$T_2P_1N_2$	1.95	6.58	0.23
$T_2P_1N_3$	2.86	5.90	0.33
$T_2P_2N_1$	3.32	5.49	0.43
$T_2P_2N_2$	2.56	5.79	0.31
$T_2P_2N_3$	2.06	4.41	0.32
SEm (±)	0.14	0.24	0.02
CD (0.05)	0.42	0.692	0.05

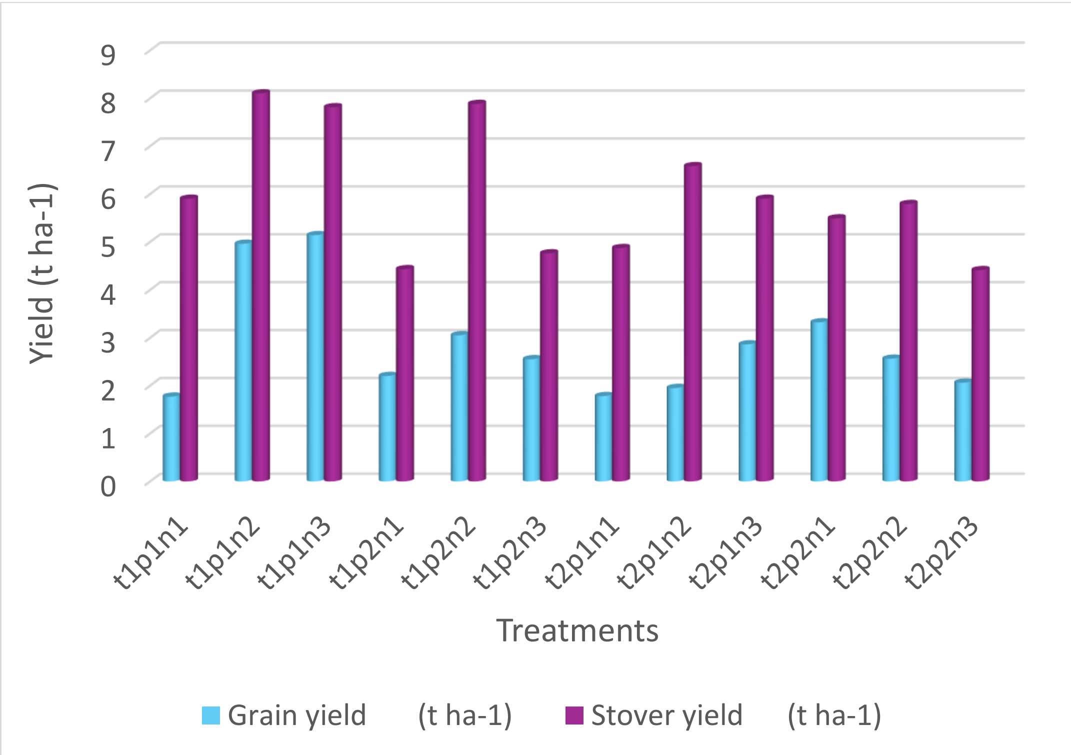

Fig. 1. Interaction effects of tillage, spacing and nutrient management on grain yield and stover yield of sorghum (t ha^{-1})

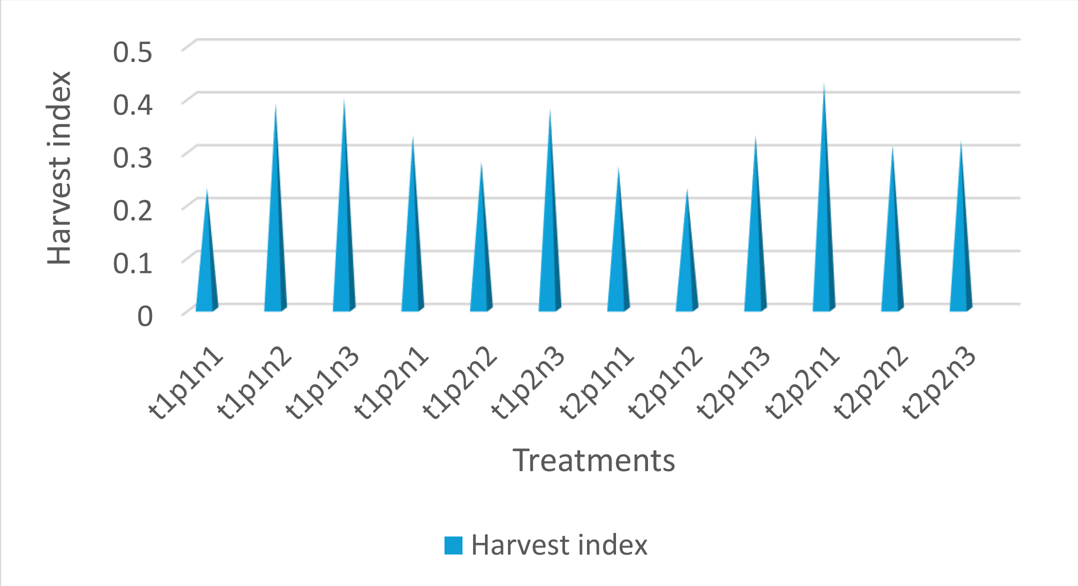

Fig. 2. Interaction effects of tillage, spacing and nutrient management on harvest index of sorghum (t ha^{-1})

Harvest Index: Harvest index was significantly superior in T_1 (zero tillage) with a value of 0.33. In case of spacing, harvest index was significantly superior in P_2 (60 cm x15 cm spacing) with a value of 0.34. The main effect of nutrient management was found to be significant on harvest index and N_3 (50:25:50 kg NPK ha^{-1}) have highest value of 0.36 (Table 2a). The T_2P_2 treatment (conventional tillage and 60 cm x 15 cm spacing) shows the highest harvest index (0.35), which was statistically on par with all other treatments except T_2P_1 (0.27). The treatment T_1N_3 (zero tillage and 50:25:50 kg NPK ha^{-1}) produced the highest harvest index (0.39). P_2N_1 treatment (60 cm x 15 cm spacing and 45:25:25 kg NPK ha^{-1}) produced highest harvest index (0.38), which was on par with P_1 N_3 (0.36) and P_2N_3 (0.35).

The treatment $T_2P_2N_1$ (conventional tillage, 60 cm x 15 cm spacing and 45:25:25 kg NPK ha^{-1}) produced highest harvest index (0.43), which was on par with $T_1P_1N_3$ (0.40), $T_1P_1N_2$ (0.39) and $T_1P_2N_3$ (0.38). The highest harvest index observed under conventional tillage and wider spacing may be due to allocation of biomass to grain relative to the total biomass was optimized in this condition. Wider spacing can reduce competition for nutrients and light, potentially leading to more efficient biomass partitioning towards grain production. However, the total biomass (grain + stover) may have been lower compared to the zero-tillage system due to less efficient nutrient use and reduced overall plant density (Kumari et al., 2021).

4. CONCLUSION

The results of the study indicated that yield attributes and yield were affected by tillage, spacing and nutrient management. Yield and yield attributes were significantly superior under zero tillage, at a closer spacing of 45 cm x 15 cm and nutrient dose of 50:25:50 kg NPK ha^{-1} and 50:25:75 kg NPK ha^{-1}. Considering yield sorghum may be recommended for cultivation in summer rice fallows with zero tillage, spacing of 45 cm x 15 cm and application of 50:25:50 kg NPK ha^{-1} along with 5 t ha^{-1} of FYM.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Chat GPT
2. COPILOT
3.GRAMMARLY
4. QUILBOT

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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