

Zero Till Water Use Efficient Rabi Sorghum (*Sorghum bicolor* L. Moench), an Effective Alternative to Water Guzzling Summer Rice (*Oryza sativa*), under Changing Climatic Scenario

Abstract: As temperature rises, the yields of food and cash crops in South Asia are expected to decline, putting pressure on food security in the region. India, home to 1.4 billion people, is ranked 101 out of 116 countries in the Global Hunger Index, indicating a serious problem. Scientists and researchers project that a 2.5 to 4.9 degrees Celsius increase in temperature across the country could lead to a decrease of 41%-52% in the wheat yield, and 32%-40% in rice. Under changing climate condition, hybrid sorghum is an effective solution towards food security, which can withstand high temperature and grow with less water over water guzzling summer rice. It has versatile utility as food grains, feed, fodder, and important feed stock for first-generation bio fuel or bio ethanol production. Zero till hybrid sorghum cultivar CSH 14, CSH 16 and CSH 23 were sown after Kharif rice in jute-rice-Rabi sorghum sequence, in winter, on 1st January 2010. The crop matured with 52.5 cm irrigation water at 120 days (30th April) and consumed 7 irrigations, 7.5 cm each. Highest sorghum grain yield was obtained from cv. CSH 14 i.e., 6.5 tonnes/ha. Its water productivity was high, 808 litre water/kg grain whereas for summer rice with same productivity (6.5t/ha) the water productivity was low, 2308 litre water/kg rice grain (irrigation requirement 150 cm). Thus, with same water, the area under sorghum will be thrice over summer rice. Gross return from hybrid sorghum was Rs.193050/ha over Rs. 132600/ha from summer rice. Rabi sorghum saved 65% (97.5 cm/ha) irrigation water which is drawn from ground water only. From 6.5 tons sorghum grain approximately 2470 litre ethanol can be produced/ha which is used as bio fuel. Replacement of summer rice by profitable drought resistant Rabi sorghum will ensure food security under changing climatic scenario and maintain sustainable ground water position in traditional rice growing belts.

Key words: Hybrid sorghum, yield, water productivity, bio ethanol, economics

1. Introduction

Sorghum (*Sorghum bicolor* L. Moench) popularly known as *jowar*, is an important staple food for millions of people in the semi-arid tropics of Asia and Africa. For 2021-22, USDA has projected world sorghum area as 41.97 million hectares (103.70 million acres) and production as 65.21 million tonnes. For India, the same was projected as 4.80 million hectares (11.86 lakh acres) and 4.60 million tonnes respectively [1]. Sorghum crop is an important source of food security which provides nutritional security (Table 1), feed, fodder and livelihood security especially to resource poor population and mainly grown on dry land areas, requires less water to mature [16]. As temperature rises, the yields of food and cash crops in South Asia are expected to decline, putting pressure on food security in the region. India, home to 1.4 billion people, is ranked 101 out of 116 countries in the Global Hunger Index, indicating a serious problem. Scientists and researchers project that a 2.5 to 4.9 degrees Celsius increase in temperature across the country could lead to a decrease of 41%-52% in the wheat yield, and 32%-40% in rice [9].

Table 1. Nutritional composition of sorghum with respect to staple cereals (per 100 g)

Source: National Institute of Nutrition (NIN), Hyderabad.

Recently the sorghum gain is also being used as feed sock for bio-fuel production. One of the potential raw materials for bio-ethanol production is white sorghum (*Sorghum bicolor*). It

Staple cereal	Protein (g)	Carbohydrates (g)	Fat (g)	Crude fibre (g)	Mineral matter (g)	Calcium (mg)	Phosphorus (mg)
Sorghum (<i>Jowar</i>)	10.4	72.6	1.9	1.6	1.6	25	222
Wheat	11.8	71.2	1.5	1.2	1.5	41	306
Rice	6.8	78.2	0.5	0.2	0.6	10	160
Maize	11.5	66.2	3.6	2.7	1.5	20	348

thrives in tropical countries and has fairly high starch content about 65%–71% typically. Sorghum seeds should be treated before using for higher ethanol production. The maximum of ethanol obtained with treated sorghum as raw material and glucoamylase enzyme concentration of 35% and 9% of yeast is 11.48% [6]. About 380 litres of ethanol could be produced per ton grain sorghum [14]. Currently, the country has 116 grain-based ethanol plants with an installed capacity of 268 crore litres, of which Punjab has the most 16 plants with a capacity of 61.67 crore litres. Maharashtra, Uttar Pradesh and Chhattisgarh have emerged as the top three destinations for grain-based ethanol plants attracting over 40 per cent of the total projects approved in the past year after the government announced a scheme for the sector. To achieve the targeted 25 per cent blending with petrol by 2024-25, the country needs 1288 crore litres of ethanol, of which grain-based plants are likely to supply 628 crore litres. With new plants approved, the total capacity of grain-based plants is likely to increase to 1,127 crore litres, according to an industry official [12].

Large area under rice-fallows is available in the states of Bihar, Orissa and Chattisgarh. Sorghum is also being produced in other non-traditional states and also increasing the overall sorghum production of the country [4]. Zero tillage saves diesel and reducing cost of land preparation and minimise greenhouse gas emission. Zero till hybrid sorghum in rice fallows was reported by [4], where 8.61 t tonne of grain yield has been reported for cv. CSH 16. In India, summer rice grown in 2.971 million hectares (ministry of Agriculture and Farmers' Welfare, Krishak Jagat, 6th May 2022) using ground water which consumes about 150 cm water per hectare to produce average 3.5-5 tonnes rice in Rabi season. Grain sorghum tolerates and avoids drought more than many other cereal crops, but the drought response of sorghum does not come without a yield loss [2]. For high production, a medium-to-late maturing sorghum cultivar (maturity within 110 to 130 days) requires approximately 450 to 650 mm of water during its growing season [10]. Scarcity of irrigation water is already wide spread across rice growing belts of the world, particularly in Rabi season. The ground water situation in West Bengal is approaching an alarming state due to its over-exploitation. The situation is not different in other States in India. Ground water inanition and erosion have become the burning issue for many of the states and planned township in India [13]. The position of ground water is also not adequate to meet the irrigation for 14 lakh ha summer rice in West Bengal alone. Again, in West

Bengal, the net return from summer rice is also very poor, a distress sale commodity now and its water use efficiency is very low. The ground water can be effectively utilised replacing traditional summer rice by Rabi sorghum. having low water requirement. To address these issues grain production ability of Rabi sorghum was tested at ICAR-CRIJAF that can grow under less water, have versatile use and more remunerative to farmers.

2. Materials and methods

A field trial was conducted at main farm of ICAR-CRIJAF, Barrackpore, West Bengal (22°45'N, 88°25'E; 9.69 m above mean sea level) in 2010 to test the feasibility of growing hybrid sorghum in Rabi season. The experimental soil was sandy loam in texture and its N, P₂O₅ & K₂O content were 350 kg/ha, 30.25 kg/ha and 175 kg/ha, respectively. The experimental soil had 44 per cent sand, 28 per cent silt and 28 per cent clay, respectively. In jute - rice - Rabi sorghum sequence, after harvesting of Kharif rice, hybrid sorghum was sown under zero tillage by drawing shallow furrows manually in between rice stubble rows on 1st January 2010. Near 10 kg seeds were sown at 45 cm x 15 cm spacing at a depth of 5-6 cm. The seeds were covered manually and a post sowing irrigation was applied for its better germination. Hybrid sorghum varieties CSH 14, CSH 16 and CSH 23 were sown in three replications. Plot sizes were 5 m x 4 m. Sorghum seeds took about 15 days to germinate due to cool air and soil temperatures. The mean maximum and minimum atmospheric temperatures of January 2010 were 23.2 °C and 9.79 °C, respectively. Soil temperature varied from 18.3 to 18.9 °C at 5 cm depth. The crop received no rain except 19.4 mm rainfall in April, otherwise it was primarily a dry weather. The sunshine hour varied from 6.82 to 8.68 hours during its growth period. Maximum and minimum humidity varied from 87-97 per cent and 42-54 percent respectively (Table 2). Thus, the climate was very favourable for growth, development and harvest of sorghum.

Initially no fertiliser was applied. At 30 days after sowing (DAS) before 2nd irrigation, 40 kg /ha N and 60 kg/ha P₂O₅ and 60 kg/ha K₂O were applied. Two split doses of nitrogen @ 30 Kg/ha were applied at 60 AS (before 4th irrigation) and 90 DAS (before 6th irrigation). Irrigations were given at 15 days intervals and were withheld from 105 DAS. This year we did not applied any pesticides. The crop matured at 120 DAS near 30th April. In Southern Bengal, up to 15th of May, normally hot and dry weather prevails and it is favourable for harvesting, threshing and drying of sorghum grains (Table 2). Matured sorghum panicles were harvested first and the left over stovers/stalks were harvested latter on. The harvested panicles were dried in sun for a week and the grains were separated from panicles by biting it on threshing floor, manually.

Table 2: Meteorological data during sorghum growth) at ICAR-CRIJAF, Barrackpore, WB (2010: January to May)

Months	Mean Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Sunshine hours	Soil temperature (°C) at 5m depth	
	Maximum	Minimum	Morning	Noon	Total		Morning	Noon
January	23.2	9.79	92.83	51.4	00	6.94	18.3	18.9
February	28.8	14.8	96.67	45.6	00	6.82	21.6	24.2
March	35.0	22.1	91.32	42.2	1.4	8.68	27.8	32.2
April	37.2	26.7	87.33	54.1	19.4	8.28	30.7	40.2
May	35.4	26.0	89.03	64.29	171	6.53	29.7	37.5

Source : ICAR- CRIJAF. Ann.Rep.2009-10, pp 90

3. Results and Discussions

Zero till sown hybrid sorghum cultivars CSH 14, CSH 16 and CSH 23, grown well under prevailing favourable weather condition in Rabi season (Table 2) at ICAR-CRIJAF, Barrackpore, and West Bengal in 2010. The crop was grown under fairly dry weather condition. The sunshine hour varied from 6.82 to 8.68 hours during its growth period. Maximum and minimum humidity varied from 87-97 per cent and 42-54 percent respectively (Table 2). Thus the climate was very suitable for growth, development and harvest of hybrid sorghum. The crop was harvested at 120 DAS, following the maturity of grains (Photo1). Higher sorghum grain yield was obtained from cv. CSH 14 and CSH 16 i.e., 6.5 and 6.2 tonnes/ha respectively [7] with a fodder yield of 8.85 and 8.86 tonnes/ha (Table 3). Yield of cultivar CSH 23 was lower (5.0 tonnes/ha) under same practices. The irrigation requirement for Hybrid sorghum was 52.5 cm. Relative merit of hybrid sorghum was compared with farmers' field mean rice data [Table 3].

Under changing climatic condition following global warming, the water productivity of crops has become very important indices to select crops by farmers that can grow in less water and sustain crop production under high temperature and erratic rainfall over space and time. Water productivity of sorghum cv. CSH 14 was high and it required only 808 litres of water to produce one kg grain (Table 3). But for summer rice with same productivity (6.5 t/ha), the water productivity was very poor i.e, 2308 litres of water were required to produce one kg rice grain. Sorghum saved huge irrigation water (65%) i.e., 97.5 cm /ha, over summer rice (150 cm/ha) which is primarily drawn from ground water (Table 3). Hence, the precious ground water can be more efficiently utilised by sorghum in Rabi season over traditional summer rice. Of late, rice crop has become very unsustainable and less profitable over others, especially because of its very high irrigation requirement. Thus, using same quantity of irrigation water, the area under sorghum could be trebled over growing traditional summer rice. Grain sorghum tolerates and avoids drought more than many other cereal crops, but the drought response of sorghum does not come without a yield loss [2]. For high production, a medium-to-late maturing sorghum cultivar (maturity within 110 to 130 days) requires approximately 450 to 650 mm of water during its growing season [10]. From 6.5 t grain sorghum approximately 2470 litres ethanol (Table 3) can be produced/ha which is used as bio fuel taking 380 litre ethanol/ton of sorghum grain [14].

The minimum support price (2022-23) of sorghum (Rs.2970/q) is much higher than fine summer rice (Rs.2040/q). Gross return from hybrid sorghum was Rs.193050/ha over Rs.132600/ha from summer rice. Thus the ground water position will be in a sustainable situation, if summer rice is replaced with hybrid sorghum under changing climatic scenario. Zero till Rabi hybrid sorghum grain yield of cv. CSH 16 was 8.61 tonne/ha while grown on rice fallows, in Nallapadu, Sripuram and Athrota villages of Guntur, district of Andhra Pradesh [4, 5]. Hoeing is recommended to conserve soil moisture and removal of weeds [8, 3, and 4]. After Kharif rice harvest, sowing of Rabi sorghum can be mechanised using Zero till seed drill, available now in abundant. To control shoot fly Phorate granules (40 kg/ha) should be applied in soil at the time of sowing. The left over stover can be utilised as fodder or fuel. The sorghum is now being used both as food and feed in India.

Table 3. Relative performances of different hybrid sorghum varieties in Rabi season under zero till cultivation

Crop	Duration (Days)	Irrigation requirement (cm)	Grain yield (t/ha)	Stover yield (t/ha)	Water productivity (litre water /kg grain)	Gross return (Rs/ha)	Ethanol production litre/ha
Sorghum Variety							
CSH 14	120	52.5	6.5	8.85	808	193050	2470
CSH 16	120	52.5	6.2	8.86	847	184140	2356
CSH 23	120	52.5	5.0	6.6	1050	148500	1900
Summer rice	Farmers field mean data of rice yield						
IR-36	120	150	6.5	6.5	2308	132600	*1898
SD ±	--	48.75	0.71	1.36	711.12	28719	274.8

*Ethanol production is 292 lit/tonnes of broken rice grain [15]





Photo 1. Panicle initiation, dough and maturity stages of hybrid Rabi sorghum and harvesting of its panicles at ICAR-CRIJAF (from top left, of 1st row to the end of 2nd row).

4. Conclusions

Adoption of Rabi sorghum replacing summer rice will sustain farmers under changing climate scenario, particularly with regards to rising temperature and scarcity of irrigation water. Grain sorghum tolerates and avoids drought more than many other cereal crops, but the drought response of sorghum does not come without a yield loss. It requires only 52.5 cm water to mature and saves irrigation water of 97.5 cm/ha over summer rice (150 cm/ha). Its water productivity is higher (808 lit/kg grain sorghum) than summer rice (2308 lit/kg rice grain). Thus, the ground water situation will be in a sustainable condition, if summer rice is replaced with hybrid sorghum under changing climatic scenario. Using same quantity of irrigation water, the area under sorghum could be trebled over the area of growing traditional summer rice. From experimental result it was observed that zero till Rabi sorghum production potential was up to 6.5 t/ha in West Bengal. This crop also produces enough fodder for cattle. Gross return from hybrid sorghum was Rs.193050/ha over Rs. Rs.132600/ha from summer rice. Thus, hybrid sorghum was more profitable over summer rice. From 6.5 t sorghum grain approximately 2470 litre ethanol can be produced/ha which is used as bio fuel. Under changing climate condition, hybrid sorghum is an effective solution towards food and nutritional security, which can withstand high temperature and grow with less water over water guzzling summer rice.

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