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

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***Author's contribution***

*The sole author designed, analysed, interpreted and prepared the manuscript.*

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## 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$^0$C 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 conditions, hybrid sorghum is an effective solution for food security, which can withstand high temperatures and grow with less water over water guzzling summer rice. It has versatile utility as food grains, feed, fodder, and an important feedstock for first-generation biofuel or *bioethanol* production. Zero till hybrid sorghum cultivars 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. The 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 the same productivity (6.5t/ha) the water productivity was low, 2308 litre water/kg rice grain (irrigation requirement 150 cm). Thus, with the same water, the area under sorghum will be thrice over summer rice. Gross return from hybrid sorghum was

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Rs.193050/ha over Rs. 132600/ha from summer rice. Rabi sorghum saved 65% (97.5 cm/ha) of irrigation water which is drawn from groundwater only. From 6.5 tons of sorghum grain, approximately 2470 litre of ethanol can be produced/ha which is used as biofuel. Replacement of summer rice by profitable drought-resistant Rabi sorghum will ensure food security under changing climatic scenarios and maintain a sustainable groundwater position in traditional rice growing belts.

*Keywords: Hybrid sorghum; yield; water productivity; bioethanol; 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 the 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 populations, and is mainly grown on dry land areas, requiring less water to mature [2]. 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 $4.9^0$C increase in temperature across the country could lead to a decrease of 41%-52% in the wheat yield, and 32%-40% in rice [3].

Recently sorghum grain is also being used as feedstock for biofuel production. One of the potential raw materials for bio-ethanol production is white sorghum (*Sorghum bicolor*). It thrives in tropical countries and has fairly high starch content about 65%–71% typically. Sorghum seeds should be treated before use for higher ethanol production. The maximum ethanol obtained with treated sorghum as raw material and glucoamylase enzyme concentration of 35% and 9% of yeast is 11.48% [4]. About 380 liters of ethanol could be produced per ton of grain sorghum [5]. 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 percent of the total projects approved in the past year after the government announced a scheme for the sector. To achieve the targeted 25 percent 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 [6,7].

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 [8]. Zero tillage saves diesel and reduces the cost of land preparation and minimize greenhouse gas emission. Zero till hybrid sorghum in rice fallows was reported by [8], where 8.61 tonnes of grain yield has been reported for cv. CSH 16. In India, summer rice is grown on 2.971 million hectares (Ministry of Agriculture and Farmers' Welfare, Krishak Jagat, 6th May 2022) using groundwater which consumes about 150 cm of water per hectare to produce an average of 3.5-5 tonnes of 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 [9]. 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].

The scarcity of irrigation water is already widespread across rice-growing belts of the world, particularly in the Rabi season. The groundwater situation in West Bengal is approaching an alarming state due to its over-exploitation. The situation is not different in other States in India. Groundwater inanition and erosion have become a burning issue for many of the states and planned townships in India [11]. The position of groundwater is also not adequate to meet the irrigation for 14 lakh ha of summer rice in West Bengal alone. Again, in West Bengal, the net return from summer rice is also very poor, a distressed sale commodity now and its water use efficiency is very low. The groundwater can be effectively utilized to replace traditional summer rice with Rabi sorghum. having low water requirements. To address these issues grain production ability of Rabi sorghum was tested at ICAR-CRIJAF which can grow under less water, have versatile use, and be more remunerative to farmers.

## 2. MATERIALS AND METHODS

A field trial was conducted at the main farm of ICAR-CRIJAF, Barrackpore, West Bengal ($22^0$45'N, $88^0$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, $P_2$O5 & $K_2O$ content were 350 kg/ha, 30.25 kg/ha, and 175 kg/ha, respectively. The experimental soil had 44 percent sand, 28 percent silt, and 28 percent clay, respectively. In the jute - rice - Rabi sorghum sequence, after harvesting Kharif rice, hybrid sorghum was sown under zero tillage by drawing shallow furrows manually in between rice stubble rows on $1^{st}$ 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 post-sowing irrigation was applied for 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 $^0$C and 9.79 $^0$C, respectively. Soil temperature varied from 18.3 to 18.9 $^0$C at 5 cm depth. The crop received no rain except 19.4 mm of rainfall in April, otherwise, it was primarily 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 percent and 42-54 percent respectively (Table 2). Thus, the climate was very favorable for the growth, development, and harvest of sorghum.

Initially, no fertilizer was applied. At 30 days after sowing (DAS) before 2nd irrigation, 40 kg /ha N and 60 kg/ha $P_2O_5$, and 60 kg/ha $K_2O$ were applied. Two split doses of nitrogen @ 30 Kg/ha were applied at 60 AS (before $4^{th}$ irrigation) and 90 DAS (before $6^{th}$ irrigation). Irrigations were given at 15 days intervals and were withheld from 105 DAS. This year we did not apply any pesticides. The crop matured at 120 DAS near $30^{th}$ April. In Southern Bengal, up to the $15^{th}$ of May, normally hot and dry weather prevails and it is favorable for harvesting, threshing, and drying of sorghum grains (Table 2). Matured sorghum panicles were harvested first and the leftover stovers/stalks were harvested later on. The harvested panicles were dried in sun for a week and the grains were separated from the panicles by bitting them on the threshing floor, manually.

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

| Staple cereal | Protein (g) | Carbohydrates (g) | Fat (g) | Crude fibre (g) | Mineral Matter (g) | Calcium (mg) | Phosphorus (mg) |
|---|---|---|---|---|---|---|---|
| Sorghum (*Jowar*) | 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 |

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

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

| Months | Mean Temperature ($^0$C) | | Relative humidity (%) | | Rainfall (mm) | Sunshine hours | Soil temperature ($^o$C) at 5cm 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, grew well under prevailing favorable weather conditions in Rabi season (Table 2) at ICAR-CRJAF, 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 percent and 42-54 percent respectively (Table 2). Thus the climate was very suitable for the growth, development, and harvest of hybrid sorghum. The crop was harvested at 120 DAS, following the maturity of grains (Fig. 1). Higher sorghum grain yield was obtained from cv. CSH 14 and CSH 16 i.e., 6.5 and 6.2 tonnes/ha respectively [12] with a fodder yield of 8.85 and 8.86 tonnes/ha (Table 3). The yield of cultivar CSH 23 was lower (5.0 tonnes/ha) under the same practices. The irrigation requirement for Hybrid sorghum was 52.5 cm. The relative merit of hybrid sorghum was compared with farmers' field mean rice data [Table 3].

Under changing climatic conditions following global warming, the water productivity of crops has become a very important indices to select crops by farmers that can grow in less water and sustain crop production under high temperatures 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 the 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 groundwater (Table 3). Hence, the precious groundwater can be more efficiently utilized by the sorghum in the Rabi season over traditional summer rice. Of late, the rice crop has become very unsustainable and less profitable than others, especially because of its very high irrigation requirement. Thus, using the 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 [9]. 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 of ethanol (Table 3) can be produced/ha which is used as biofuel taking 380 litre ethanol/ton of sorghum grain [5].

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 groundwater position will be in a sustainable situation if summer rice is replaced with hybrid sorghum under changing climatic scenarios. 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 [8,13]. Hoeing is recommended to conserve soil moisture and remove weeds [14,15,8]. After the Kharif rice harvest, sowing of Rabi sorghum can be mechanized using Zero till seed drill, available now in abundance. To control shoot fly Phorate granules (40 kg/ha) should be applied in the soil at the time of sowing. The leftover stover can be utilized 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 L/tonnes of broken rice grain [16]*

**Fig. 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 scenarios, particularly with regard 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 of water to mature and saves irrigation water of 97.5 cm/ha over summer rice (150 cm/ha). Its water productivity is higher (808 L/kg grain sorghum) than summer rice (2308 L/kg rice grain). Thus, the groundwater 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 the 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.132600/ha from summer rice. Thus, hybrid sorghum was more profitable than summer rice. From 6.5 t sorghum grain, approximately 2470 litre ethanol can be produced/ha which is used as biofuel. Under changing climate conditions, hybrid sorghum is an effective solution for food and nutritional security, which can withstand high temperature and grow with less water over water guzzling summer rice.

## COMPETING INTERESTS

Author has declared that no competing interests exist.

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