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Dates of Sowing and Residual Nitrogen Levels on Growth, Yield and Uptake in Sorghum under Zero-till Conditions in Coastal Belts of India

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Authors' contributions

This work was carried out in collaboration among all authors. Author VRKM designed the study. Author BVSK conducted the experiment and collected data and performed the statistical analysis and wrote the first draft of the manuscript. Authors MSR and PRKP managed the analyses of the study. Author BVSK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *rabi* seasons of 2017-18 and 2018-19 at College farm, Agricultural College, Bapatla, situated at 8 km away from the Bay of Bengal in the Krishna Agro-climatic Zone of Andhra Pradesh state of India to study the influence of dates of sowing and residue levels of nitrogen on growth, yield and uptake of sorghum under zero- till conditions in coastal rice fallows. The experiment was designed in RDB with factorial concept and replicated thrice. The treatments consisted of three dates of sowing (Factor-1): S_1: 49 MW (5^{th} December); S_2: 50 MW (15^{th} December); S_3: 52 MW (25^{th} December) and four residual nitrogen levels (Factor-2) applied to the previous rice crop: N_1-60 kg, N_2-80 kg, N_3-100 kg and N_4-120 kg N ha^{-1}. Sorghum was grown as a residual crop under zero tillage in rice fallows. Significant higher improvement in drymatter (10395

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and 10269 kg ha^{-1}), length of spike (24.8 and 24.5 cm), grain (3839 and 3602 kg ha^{-1}) and stover yields (7446 and 7298 kg ha^{-1}) and nitrogen uptake by grain (51.9 and 42.9 kg N ha^{-1}) and stover (42.0 and 39.9 kg N ha^{-1}) was recorded in early date of sowing i.e. 49 MW in both the seasons 2017-18 and 2018-19, respectively, and among the residue nitrogen levels 120 kg N ha^{-1} showed highest drymatter (10661 and 10484 kg ha^{-1}), length of spike (25.0 and 24.8 cm), grain (4078 and 3815 kg ha^{-1}) and stover yields (7518 and 7443 kg ha^{-1}) and nitrogen uptake by grain (54.6 and 46.6 kg N ha^{-1}) and stover (44.3 and 42.1 kg N ha^{-1}) compared to other nitrogen levels in both the seasons. Based on above results, early sowing of sorghum with high residue nitrogen levels could be recommended to small and marginal farmers in coastal belts of India for higher productivity.

Keywords: Sorghum; dates of sowing; nitrogen; drymatter; grain yield; stover yield.

1. INTRODUCTION

Grain sorghum (*Sorghum bicolor* L. Moench) popularly known as jowar (Hindi) and jonna (Telugu) is the fifth most important cereal grown in the world and fourth most important cereal consumed in India. Globally, sorghum is cultivated in an area of 42 m ha producing 59.3 m t at an average productivity of 1.41 t ha^{-1} [1]. In India the crop is grown during both *kharif* and *rabi*. *Kharif* grain is used both for human consumption and animal feed, whereas, *rabi* produce is primarily used for human consumption in India [2]. Sorghum is an essential cereal crop for resource poor, small and marginal farmers in semi-arid regions of India, occupying an area of 3.84 m ha with a productivity of 979 kg ha^{-1} and a total production of 3.76 m t [3]. Even though sorghum is used for various uses as food, feed, fodder and biofuel, the area under grain sorghum in India has declined from 10.25 m ha in 1999-2000 to 5.82 m ha in 2014-15. The productivity of sorghum in the country is very less (average yield is < 1.0 t ha^{-1}) and the crop can be cultivated in rice fallows under zero tillage condition.

In coastal regions of India, particularly in Andhra Pradesh cereal-millet is one of the predominant cropping system in both rainfed and irrigated areas. If rice-sorghum crop sequence is introduced in the Krishna agro-climatic zone of Andhra Pradesh, it will benefit small and marginal farmers' to a great extent in getting higher monetary returns in addition to enrichment of soil health. Rice- sorghum cropping systems, can alleviate the determinants like delayed transplanting of rice owing to late release of water in canals and severe infestation of yellow mosaic virus and weeds in blackgram. Combined with continuous cultivation of maize in rice fallows initially gave higher income to the farmers and over years the production reached a plateau and recent incidence of pests in *rabi* maize, in coastal belt made the rice-maize production system unsustainable [4].Therefore, introduction of rice-sorghum with low input under coastal agro-ecosystem conditions may sustain the economy of the farmers of the Coastal belt of Andhra Pradesh [5].

Moreover, its resilience to high temperature and moisture stress conditions makes the crop a climate-ready crop. Sowing date has been observed to indirectly affect grain quality in sorghum [6]. Early sowing, *vis-a-vis* late sowing affects grain yield and productivity. Sowing early provides longer growing period and productive grain filing, while late sowing was found to shorten cycle leading to low yield and poor quality grain [7]. Currently, limited information is available on the effect of sowing dates on sorghum. Since sorghum grain is nutritionally rich, there is a need to address the effect of sowing date on sorghum grain quality and productivity.

Presently research information on standard production practices for zero-till cultivation in coastal rice-fallows are lacking. To develop less input based cropping system for small and marginal farmers the sorghum crop was grown in rice fallows as a residue crop which can reduce the costs on inputs by using improved sorghum varieties/hybrids. Under optimal conditions, sorghum has a high yield potential comparable to other cereals such as rice, maize or wheat [8]. Increase in productivity depends mainly on the efficient use of available appropriate technologies rather to adoption of new technologies. Chimai [9], noted that, for the small and marginal farmers, production is affected due to differences in input use efficiency and other regional and farm specific socio-economic factors. Taking advantage of residual moisture, saving in cost on land preparation, available high yielding varieties/hybrids, reduced fertilizers and weed management can ensure small farmers an assured yield and contribute towards food security ultimately in alleviation of poverty. Therefore, the current study was undertaken to identify optimum date of sowing for sorghum and its response to residual nitrogen in coastal rice fallows.

2. MATERIALS AND METHODS

2.1 Growth Conditions and Plant Materials

The experimental site is situated at an altitude of 5.49 m above mean sea level, 15^0 54'North latitude, 80^0 25' East longitude and about 8 km away from the Bay of Bengal in the Krishna Agro-climatic Zone of Andhra Pradesh state of India. Field experiment was laid out on clay loam soil of Agricultural College Farm, Bapatla during *rabi* seasons 2017-18 and 2018-19.

The soil was slightly alkaline in reaction (pH 7.8) and medium in organic carbon (0.50%), low in available nitrogen (242 kg ha^{-1}), medium to high in available phosphorus (38 kg ha^{-1}) and high in available potassium (434 kg ha^{-1}).

Rice crop was sown on *kharif* seasons of 2017 and 2018 with different duration varieties under direct seeded conditions. After the harvest of rice crop of different durations as a zero till crop sorghum was sown on the same day of harvest.

The weekly mean maximum temperature varied from 29.9 to 35.0^0C and 26.6 to 33.8^0C during *rabi* 2017-18 and 2018-19, respectively. The mean minimum temperature for the corresponding period varied from 16.0 to 25.0^0C (2017-18) and 14.6 to 25.5^0C (2018-19). The average maximum and minimum temperatures were 31.5 and 18.8^0C during *rabi* 2017-18, and 30.8 and 20.1^0C during *rabi* 2018-19, respectively. The average relative humidity 72.1 and 76.8 per cent during *rabi* 2017-18 and 2018-19, respectively. A total rainfall received during *rabi* 2017-18 was nil and 52.1 mm was received in 2 rainy days during *rabi* 2018-19. Whereas, the available bright sunshine hours ranged between 4 to 9 hours day^{-1} and 2 to 9 hours day^{-1} during *rabi* 2017-18 and 2018-19, respectively (Table 1).

2.2 Experimental Design

The experiment was laid out in Randomized Block Design with factorial concept and replicated thrice. The treatments consisted of three dates of sowing (Factor-1): S_1: 49 MW (5^{th} December after the harvest of rice variety NLR-34449); S_2: 50 MW (15^{th} December after the harvest of NLR-145); S_3: 52 MW (25^{th} December after the harvest of rice variety BPT-5204) and four residual nitrogen levels (Factor-2) applied to the previous rice crop: N_1-60 kg, N_2-80 kg, N_3-100 kg and N_4-120 kg N ha^{-1}. Sorghum was grown as a residual crop under zero tillage in rice fallows. Sorghum cultivar, MLSH-296, developed by Mahendra hybrid seeds company private limited Hyderabad and with 100 to 110 days duration was used. Other recommended agronomic practices and plant protection measures were taken up timely. Pre and post-harvest observations in respect to both growth and yield parameters were recorded following standard procedures.

2.3 Measurements

Five successive plants from the second border row from each plot were taken for recording of observations at the time of harvest. The plants were shade dried for 48 hrs followed by hot air oven drying at 65^0C till constant weight was obtained. The drymatter accumulation was expressed as kg ha^{-1}. The length of the panicle from tagged five plants was measured from base to tip of the panicle and the mean value was computed as panicle length in centimeter (cm). The weight of thousand grains was recorded by using electronic digital balance and expressed in grams (g). The sun dried ears from net plot area were threshed, cleaned and weight of the grain was recorded as grain yield per net plot area. Grain yield ha^{-1} was worked out and expressed in kg ha^{-1}. After harvest the stover from each net plot was dried in the sun and weight was expressed in kg ha^{-1}.

2.4 Nitrogen Uptake

The plant samples collected for drymatter accumulation from different treatments were oven dried, powdered in grinder and passed through 2 mm sieve. Total N content in these ground samples was measured colorimetrically following H_2SO_4 wet digestion, as described by Mizuno and Minami [10]. Uptake of N by grain and stover was calculated by multiplying the nitrogen content with the respective drymatter accumulation, which were summed up to estimate total nitrogen uptake of grain and stover at harvest.

Table 1. Average weekly weather data during *rabi* seasons of 2017-18 and 2018 -19 during sorghum crop growth period

SMW	Month	2017-18						2018-19					
		Mean temp (^0C)						Mean temp (^0C)					
		Max.	Min.	Mean RH (%)	Rainfall (mm)	Rainy days	Sunshine hours (hrs day^{-1})	Max.	Min.	Mean RH(%)	Rainfall (mm)	Rainy days	Sunshine hours (hrs day^{-1})
51	17th -23rd Dec	30.7	17.2	72.3	-	-	4.0	26.6	18.3	82.6	47.0	1	2.3
52	24th -31st Dec	30.1	16.5	71.2	-	-	5.0	29.1	17.7	78.3	00.0	-	3.1
1	01st-07th Jan	30.5	16.9	74.0	-	-	5.0	29.0	14.6	72.9	00.0	-	4.4
2	8th -14th Jan	30.1	18.2	74.7	-	-	4.0	29.9	15.9	75.5	00.0	-	2.5
3	15th -21st Jan	29.9	17.4	74.3	-	-	5.0	29.8	17.7	78.9	00.0	-	2.5
4	22nd -28th Jan	30.1	16.9	75.4	-	-	7.0	29.6	18.7	79.8	00.0	-	4.9
5	29th Jan-04th Feb	31.6	16.0	60.8	-	-	8.0	29.0	16.7	73.3	01.0	-	5.8
6	05th -11th Feb	30.6	19.3	75.4	-	-	6.0	30.7	20.1	76.6	00.0	-	6.4
7	12th-18th Feb	31.2	18.9	73.4	-	-	7.0	31.1	20.2	80.6	00.2	-	7.2
8	19th-25th Feb	31.0	17.8	68.4	-	-	7.0	33.0	21.1	72.9	00.0	-	8.5
9	26th Feb-4th Mar	35.0	18.6	61.2	-	-	6.0	32.1	24.0	77.9	03.9	1	7.2
10	5th -11th Mar	32.8	18.9	71.5	-	-	8.1	32.9	25.5	79.4	00.0	-	7.4
11	12th -18th Mar	32.6	21.8	73.8	-	-	8.0	33.4	21.8	70.9	00.0	-	8.3
12	19th -25th Mar	33.8	22.9	76.6	-	-	7.6	32.9	24.9	76.1	00.0	-	9.0
13	26th Mar-1st Apr	33.0	25.0	78.1	-	-	8.6	33.8	24.9	76.7	00.0	-	9.0
Mean	**-**	**31.5**	**18.8**	**72.1**	**-**	**-**	**6.4**	**30.8**	**20.1**	**76.8**	**-**	**-**	**5.9**
Total	**-**	-	-	-	-	-	-	-	-	-	**52.1**	**2.0**	-

2.5 Statistical Analysis

Observed data were subjected to statistical analysis by following appropriate method of analysis of variance (ANOVA) as outlined by Fisher' s [11] and appropriate standard error for each of the factor was worked out. Significance of differences among treatment effects was tested by F test. Critical difference (CD) was worked out at 5 per cent level of significance.

3. RESULTS AND DISCUSSION

3.1 Crop Components

Significant differences between different dates of sowing of sorghum and all crop characteristics were observed among the components under study (Drymatter, Length of spike, grain yield, stover yield and nitrogen uptake by grain and stover) in both the seasons (Table 2). Sorghum crop sown on 49 MW (5^{th} December) was found significantly superior over other dates of sowing in parameters such as drymatter 10395 and 10269 kg ha^{-1} with rate of increase 8.31% and 8.87%, length of spike 24.8 and 24.5 cm, and grain yield 3839 and 3602 kg ha^{-1} with rate of increase 10.76% and 11.89%, stover yield being 7446 and 7298 kg ha^{-1} for seasons 2017-18 and 2018-19, respectively. Weight of 1000 grains was not influenced by dates of sowing. These results were in conformity with the findings of Karhale et al. [12] who reported that drymatter accumulation is the expression of growth and development of different morphological parameters. The higher drymatter production with early date of sowing which could be attributed to cumulative effect of more plant height and optimum weather conditions like higher bright sunshine hours, which might have increased photosynthesis and in turn drymatter production. Crop was sown after the harvest of short duration rice variety might have experienced better duration, quality and intensity of light, due to more interception that resulted in higher drymatter. Murthy [13] also reported that crop phenology is largely dependent on weather elements *viz.*, temperature, solar radiation, rainfall *etc.,* and drymatter production is a function of these weather elements. The role of photosynthetically active radiation in photosynthesis in sorghum crop was more predominant in increasing grain and stover yields. These findings were in ordinance with Dera et al. [14] who reported that favourable climatic conditions created during grain filling stage of sorghum caused a better sink-source relationship and higher grain and stover yield when sorghum was sown during early conditions.

The results from Table 2 indicated an increase in all crop components under study with increase in residual nitrogen levels. The highest dose of nitrogen 120 kg N ha^{-1} was significantly influenced and recorded highest values in all crop components except 1000 grain weight during both the seasons. Drymatter was recorded as 10661 and 10484 kg ha^{-1} with the rate of increase 14.40% and 13.35%, length of spike being 25.0 and 24.8 cm, grain yield 4078 and 3815 kg ha^{-1} with rate of increase 24.70% and 23.98%, stover yield 7518 and 7443 kg ha^{-1} with rate of increase 9.48% and 11.73% for seasons 2017-18 and 2018-19, respectively, whereas, no significant increase was noted in weight of 1000 grains.

The highest drymatter accumulation of sorghum was found in 120 kg N ha^{-1} residual nitrogen when applied to the preceding rice crop and might be due to an adequate supply of nitrogen attributed to higher production of green leaves increasing photosynthetic surfaces, with increased chlorophyll content, enabling the plants to have increased photosynthesis efficiency were also reported by Yakadri and Murali [15]. These results are also in agreement with Sami et al*.* [16] who reported that the increased panicle length at high level of residual nitrogen might be due to higher nitrogen uptake, who also stated that increase in grain yield was induced by higher nitrogen fertilization rates associated with the generation of strong sinks and the activity of source The significant increase in grain yield of sorghum from 60 kg N ha^{-1} to 120 kg N ha^{-1} might be due to well-balanced supply of nitrogen which resulted higher net assimilation rate and increased grain yield [17] and also stated that proper rates of nitrogen levels were critical for meeting crop needs, and considerable opportunities existed for yield improvement. The results are also in line with the earlier findings of Mishra et al. [18] and who stated that continuous and adequate availability of nutrients which might increased the leaf area duration and photosynthetic rate. This inturn, increased the drymatter accumulation and resulted in more stover yield.

3.2 Nitrogen Uptake

Significant differences were observed among different dates of sowing and nitrogen uptake by grain and stover yield during both the seasons

Table 2. Effect of different dates of sowing and residual nitrogen levels on growth, yield and uptake in sorghum crop during *rabi* seasons of 2017-18 and 2018-19

Parameters / Treatments	Season 2017-18							Season 2018-19						
	Drymatter (kg ha^{-1})	**Length of spike (cm)**	**Wt. of 1000 grains (g)**	**Grain yield (kg ha^{-1})**	**Stover yield (kg ha^{-1})**	**Nitrogen uptake by Grain (kg ha^{-1})**	**Nitrogen uptake by Stover (kg ha^{-1})**	**Drymatter (kg ha^{-1})**	**Length of spike (cm)**	**Wt. of 1000 grains (g)**	**Grain yield (kg ha^{-1})**	**Stover yield (kg ha^{-1})**	**Nitrogen uptake by Grain (kg ha^{-1})**	**Nitrogen uptake by Stover (kg ha^{-1})**
Dates of sowing (Factor 1)														
S_3: 49 MW	10395	24.8	23.9	3839	7446	51.9	42.0	10269	24.5	23.7	3602	7298	42.9	39.9
S_1: 50 MW	9890	24.5	24.0	3659	7102	47.0	38.9	9759	24.3	23.7	3429	6962	41.6	36.9
S_2: 52 MW	9597	24.0	24.0	3466	6992	42.6	39.6	9432	23.7	23.6	3219	6854	39.3	37.6
S. Em±	215.6	0.21	0.10	91.39	125.97	1.67	0.82	187.73	0.20	0.10	95.83	123.54	0.96	0.78
CD (P=0.05)	632	0.6	NS	268	369	4.9	2.4	551	0.6	NS	281	362	2.8	2.3
Nitrogen levels (Factor 2)														
N_1: 60 kg ha^{-1}	9319	23.8	23.8	3270	6867	39.9	36.4	9249	23.3	23.6	3077	6661	38.3	34.6
N_2: 80 kg ha^{-1}	9770	24.2	23.9	3532	7095	45.1	38.9	9697	23.9	23.7	3266	6953	40.9	37.0
N_3: 100 kg ha^{-1}	10091	24.7	24.0	3738	7239	49.0	40.9	9850	24.6	23.8	3508	7094	42.9	38.8
N_4: 120 kg ha^{-1}	10661	25.0	24.0	4078	7518	54.6	44.3	10484	24.8	23.8	3815	7443	46.6	42.1
S. Em±	248.9	0.24	0.12	105.53	110.65	1.93	0.94	216.77	0.23	0.11	145.46	142.65	1.11	0.90
CD (P=0.05)	730	0.7	NS	309	427	5.5	2.8	636	0.7	NS	324	418	3.2	2.4

MW: Meteorological Week

Crop sown on 49 MW (5th December) was found significantly higher in nitrogen uptake by grain (51.9 and 42.9 kg N ha^{-1}) and stover (42.0 and 39.9 kg N ha^{-1}) compared to 52 MW (25th December) sown crop with lower uptake of nitrogen by grain 42.6 and 39.3 kg N ha^{-1} during the seasons 2017-18 and 2018-19, respectively. Significant differences were observed between residue levels of nitrogen and nitrogen uptake by grain and stover during both seasons. Residual level of 120 kg N ha^{-1} was found significantly superior with showing highest nitrogen uptake by grain (54.6 and 46.6 kg N ha^{-1}) and stover (44.3 and 42.1 kg N ha^{-1}) compared to 60 kg N ha^{-1} which recorded lower uptake of nitrogen by grain 39.9 and 38.3 kg N ha^{-1} in 2017-18 and 2018-19, respectively. This variation in characteristics is attributed to rice genotype which reflected on plant capability to absorb nitrogen from the soil. Nitrogen uptake by grain and straw was significantly highest when the sorghum crop was sown after the harvest of early maturing variety NLR-34449 and this might be due to more availability of nutrients and less uptake by variety NLR-34449 that benefited the succeeding sorghum crop with the highest nitrogen uptake. These results are in compliance with the finding of Kumar et al. [19].

4. CONCLUSION

Based on the above results and findings it could be concluded that 49 MW sowing was superior over rest of the dates and among the residual nitrogen levels 120 kg N ha^{-1} produced higher grain and stover yields. It is therefore recommended that sowing may be done in 49MW and with high nitrogen residues in soil can have highest grain and stover yields under zero-till conditions in coastal belts of India.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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