Optimising sowing window for *Sorghum bicolor* L. and *Panicum sumatrense* L. in semiarid tropics

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Abstract

Rain-dependant farming is prevalent in semiarid tropics and in Southern parts of India; farmers widely cultivate sorghum without scientific understanding of distribution as well probable receipt of rainfall. There is lack of knowledge about correct 'sowing window' which often leads to low yield and complete crop failure. The objective of this paper was to assess the quantum of rainfall received during the last 20 years and determine the probable on set and continuity of rainfall on weekly basis so as to raise a crop under rain-dependant situations. The field experiment was laid out in Factorial Randomized Block Design (FRBD) with 3 replications and data were statistically analysed in AGRES software. The treatments comprised of Sorghum (*Sorghum bicolor* L.) (C_1) and little millet (*Panicum sumatrense* L.) (C_2) as factor one (crops) and sowing window based on standard meteorological week (SMW) *viz.*, sowing at 31st SMW based on farmer's practice (M_1), Sowing at 33rd SMW based on 50% rainfall probability with 100% recommended doses of fertilizers (M_2), Sowing at 38th SMW based on 75% rainfall probability with 100% recommended doses of Nitrogen, Phosphorus and potassium (M_3), Sowing window based on current weather forecast-35th SMW (M_4), as factor two. The study indicated Sorghum (C_1) sowing on 38th standard meteorological week (M_3) is ideal to get maximum yield under rainfed condition.

Abbreviations

B:C ratio	Benefit cost ratio
CD	Critical difference
DMP	Dry matter production
GDP	Gross domestic product
LAI	Leaf area index
LGP	Length of growing period
NPK	Nitrogen, phosphorus, and potassium
RDF	Recommended dose of fertilizers
SARIMA	Seasonal autoregressive integrated moving average
SEd	Standard error of deviation
SMW	Standard meteorological week

Introduction

Rainfed agriculture plays an important economic role in the life of farmers in semi-arid tropical countries, especially in India. Though India has majority of the cultivated lands under rainfed situations, the share of rainfed agriculture in the Gross Domestic Product (GDP) had steadily declined from 55.4 per cent in 1950-51 to 14.3 per cent in 2010-11. Nevertheless, in recent times, the contributions from the rainfed agriculture towards GDP is showing a positive trend with a share of 20 per cent for the first time in the last 17 years, making it the sole bright spot in GDP performance during 2020-21, according to the Indian Economic Survey, 2020-2021. This survey further indicated that the climate resilient agriculture by the farming community made, rainfed agriculture is the only sector to have clocked positive growth of 3.4 per cent at constant prices in 2020-21, while other sectors slid. India attained self-sufficiency in food production through the Green Revolution, which had transformed many frontiers in farming, but the impacts of it failed to reach the drylands/rainfed regions. Even with the little care, at the global level, India presides in rainfed farming which contributes to about 44% of food grain production. It provides support for realizing full potential in rainfed farming with scientific technological interventions. The factors like

Table 1 - Effect of different sowing dates on growth parameters in sorghum and little millet

Treatments	Plant height at harvest(cm)	LAI at harvest	Length of panicle (cm)	Weight of panicle (g)
Factor 1: Crops				
Sorghum	201.07	5.62	17.17	91.83
Little millet	92.86	0.64	40.63	4.60
S.Ed	0.28	0.04	0.18	0.56
CD (p=0.05)	0.60	0.10	0.38	1.21
Factor 2: Sowing based on SMW				
Sowing at 31st SMW based on farmer's practice	140.78	2.93	28.94	40.83
Sowing at 33rd SMW based on 50% rainfall probability with 100% recommended doses of PK	136.86	2.64	27.84	37.26
Sowing at 38th SMW based on 75% rainfall probability with 100% recommended doses of NPK	156.64	3.59	30.17	61.57
Sowing window as per the current weather forecast (35th SMW in this study)	153.56	3.36	28.77	53.21
S.Ed	0.56	0.09	0.36	1.12
CD (p=0.05)	1.20	0.20	0.77	2.42

SMW-Standard Meteorological Week; LAI-Leaf Area Index

water shortage caused by uncertain and vagaries of monsoon rain, land denudation, low productivity, and changing global environment are the major threats in the rainfed/dryland region and any attempt made to address these issues would contribute to improve food production.

In arid or semi-arid conditions, the soil moisture is the major limiting factor for rain-dependant crop production. The quantum of rain received and its distribution during the cropping season decide the soil moisture storage and availability, which dictates the length of the growing period (LGP). Both surplus and deficit rainfall cause detrimental effects on crop growth and yields as the rainfed crops solely rely on monsoon rains for growth. However, the experiences gained by the farming community would give a barren idea about the onset of rainfall and probable distribution which could be an essential input for crop planning in rainfed ecosystems. To ensure a good crop under rain-dependent cultivation, a rainfall probability of 80 per cent could safely be taken as assured rainfall, but 50 per cent probability is the medium limit for taking risk as confirmed by Gupta *et al.* (1975). While Ian Stewart (1988) found a novel rain-dependent cultivation method and named it as Response Farming, which is defined as a flexible system of farming in which key decisions affecting crop water utilization and crop yield are modified each season in response to pre-season and early predictions of seasonal rainfall parameters. This pushed us to study and test the response farming in a rain-dependent region of South India. The study was carried out at Annur block of Coimbatore district, India. In this block, for years, sorghum has been the predominant crop cultivated by the farmers under rain-dependent situations. Nevertheless, the farmers lack knowledge about the correct 'sowing window' which often keeps the farmers fingers crossed about the outcome of the sown crop. This study addressed this problem and fixed the correct time of sowing. The prime objective of this research was to analyze the previous 20 years rainfall and to determine the probable onset as well as continuity in receipt of rainfall on weekly basis, so as to fix the appropriate time of cultivating a crop under rain-dependant situations. To begin the research, initially, we surveyed the farmers of the selected rural area to enquire about various cultivation practices adopted by them like crops grown, month and time of sowing, rainfall receipts and experiences in crop failures etc. Most farmers opined that many times crops were just harvested for fodder rather than grain (food) as the monsoon rains stopped abruptly as there existed a mismatch between the sowing time and the crop maturity period. Secondly, we gathered daily rainfall data from the authentic sources for 20 years and predicted the certainty of onset and withdrawal of monsoon rains in a year. Thirdly, we conducted on-site field experimentation in one of the farmers' fields to generate hands-on information and to get the correct sowing window for sowing of crops to be grown purely under rain-dependent monsoon rains without any external application of water (Irrigation).

Material and methods

Study location

India holds 143 million hectares of arable land and of that, 108 million hectares fall under rain-dependent farming with a semi-arid tropical climate which is spread across India. Nearly 128 districts encompassing different agro-ecological zones often face the dryland consequences. The study site also falls in this catego-

Table 2 - Effect of different sowing dates on yield parameters in sorghum and little millet

Treatmental combination	Straw yield (kg/ha)	Grain yield (kg/ha)
Sorghum-sowing at 31st SMW based on farmers practice	11333.33	670.00
Sorghum-sowing at 33rd SMWbased on 50% rainfall probability with 100% recommended doses of NPK	4440.00	476.66
Sorghum-sowing at 38th SMW based on 75% rainfall probability with 100% recommended doses of NPK	19900.00	843.33
Sorghum-Sowing window as per the current weather forecast (35th SMW in this study)	15866.66	753.33
Little millet-sowing at 31st SMW based on farmers practice	6856.66	288.33
Little millet- sowing at 33rd SMWbased on 50% rainfall probability with 100% recommended doses of NPK	5070.00	271.66
Little millet- sowing at 38th SMW based on 75% rainfall probability with 100% recommended doses of NPK	11333.33	390.00
Little millet- Sowing window as per the current weather forecast (35th SMW in this study)	8893.33	342.00
S.Ed	1282.88	16.56
CD (p=0.05)	2751.80	35.52

ry which is located in the countryside of Coimbatore district, Southern parts of India named Annur block, and is situated in the Western agro climatic zone of Tamil Nadu State of India, which falls under semi-arid tropical climate with a temperature range of 26-41°C. This block receives an annual rainfall of 546 mm, mostly benefitted from the northeast monsoon period during October-December. It is located at 11.21° N latitude and 77.04° E longitude with an altitude of 286.11 meters above mean sea level.

Farmer's survey

A preliminary in-person survey was conducted in interactive mode with farming community to gather information on the problems encountered by the farmers in the study site. A total of 30 farmers were selected at random in a walking survey in the farm lands and those farmers who came across were utilised for the study to collect information. From the interactions with them, it was learnt that 23 of them had only school education and own a farm holding of 2-3 hectares. Most of the farmers told that taking decision on time of sowing the crop is a big challenge to them, yet they have been practicing crop cultivation and animal husbandry. From the sources, it was understood that almost all the farmers (83 percent) have been cultivating crops under rain-dependent situation and remaining 17% have access to irrigation from ground water (Deepika et al 2020).

Analysing rainfall for crop planning

As a part of the study, 24-hour daily rainfall data (2000-2019) were collected from the office of the Assistant director of Agriculture, Annur block, Coimbatore district, Tamil Nadu and used for analysis. The statistical analyses of weekly rainfall, the onset and termination of the rainfall in a calendar year, monthly quantum of rain received were done. Then, the data were subjected to time series analysis using Seasonal Autoregressive Integrated Moving Average (SARIMA) Model to forecast the sowing windows/dates. Initial and conditional probability analysis with the 20 years rainfall data were made to find the utmost probability of rainfall dates for crop cultivation.

'On site' field experimentation

Based on the farmers' survey and rainfall analysis, finally, it has been decided to initiate a field trail to fix the time of sowing with farmers' participatory mode

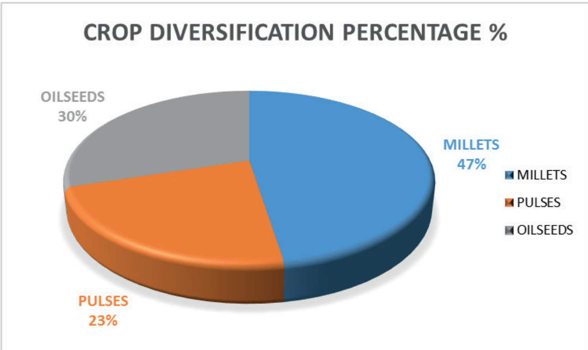

Fig. 1 - Crop diversification percentage in Annur block

during 2020. The field experiment was designed at the Department of Agronomy, Agricultural College and Research institute, Tamil Nadu Agricultural University, Madurai and was carried out in the farmer's field in the countryside of Coimbatore district, Tamil Nadu, India. The experimental field was geographically situated at 11.21° N latitude and 77.04° E longitude with an altitude of 286.11 meters above mean sea level. The soil is black sandy loam in nature. A statistical design of Factorial Randomized Block Design (FRBD) with two factors and replicated thrice with 8 treatment combinations was adopted. The treatments comprised of two crops *viz.*, Sorghum (C1) and Little millet (C2) as factor one and four sowing windows *viz.*, sowing based farmer's practice (M1) i.e. on 31st standard meteorological week (SMW); Sowing at 33rd SMW based on 50% rainfall probability (M2); Sowing at 38th SMW based on 75% rainfall probability (M3), Sowing window as per the current weather forecast, for this season on 35th SMW (M4) as factor two. For treatment (M4), the current weather forecast given by Agro Climatology Research Centre, Tamil Nadu Agricultural University, Coimbatore, India was used.

The rainfall probability was derived by using the SARIMA model helps in fixing sowing windows. The resultant from SARIMA Model shows the onset of effective rainfall ranges between 31st standard meteorological week and terminates on 42nd standard meteorological week for that region.

The crops were sown and fertilised with recommended doses of Nitrogen (N), Phosphorus (P) and Potassium (K) for both crops and were applied as basal nutrition and before sowing. The seeds were treated with 2% KCl and sown to impart a kind of drought tolerance and all the crop management practices were followed as per the recommendations in the Department of Agriculture and Tamil Nadu Agricultural University (www.agritech.tnau.ac.in), India.

Biometric observations recorded and procedures

For recording biometrics, plant height is measured using a ruler from the collar region (point on the stem where the roots start to grow) to the highest point of a fully expanded leaf and was expressed in centimetres. The leaf area index is determined by measuring the leaf area per plot and dividing it by the land surface area of the plot.

Statistical analysis

The data were statistically analysed by means of Fisher's method as suggested by Gomez and Gomez (1984). All the growth, yield and quality parameters were subjected to analysis of variance (ANOVA) and

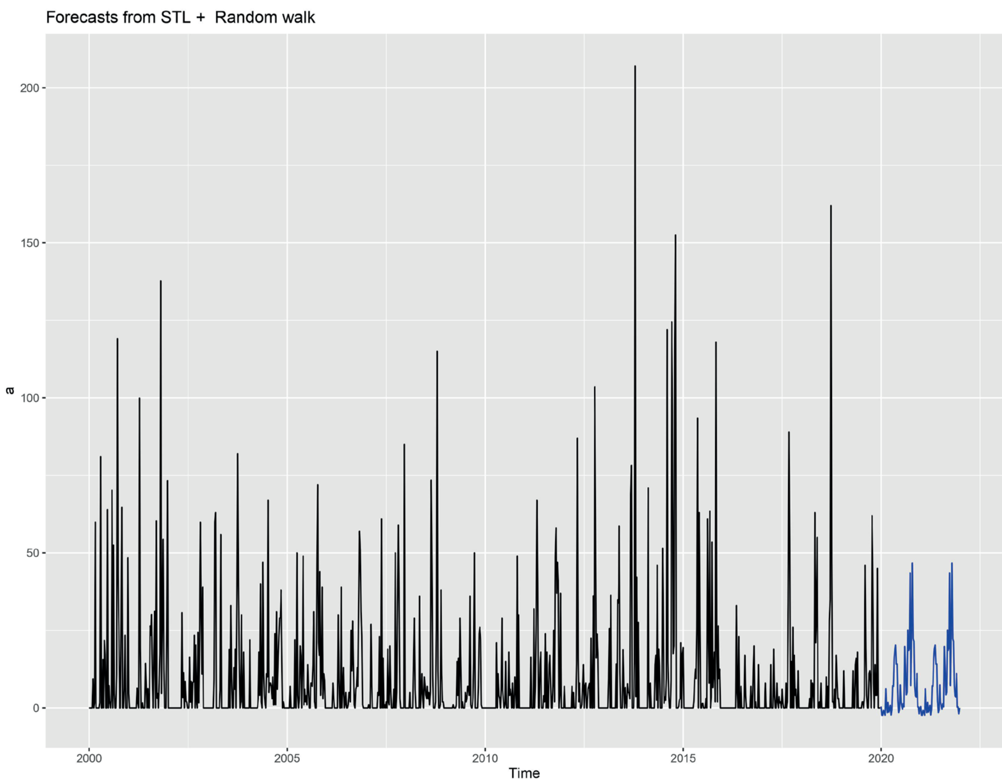

Fig. 2 - Rainfall data used for analysis (2000-2019) Vs Rainfall forecasted (2020)

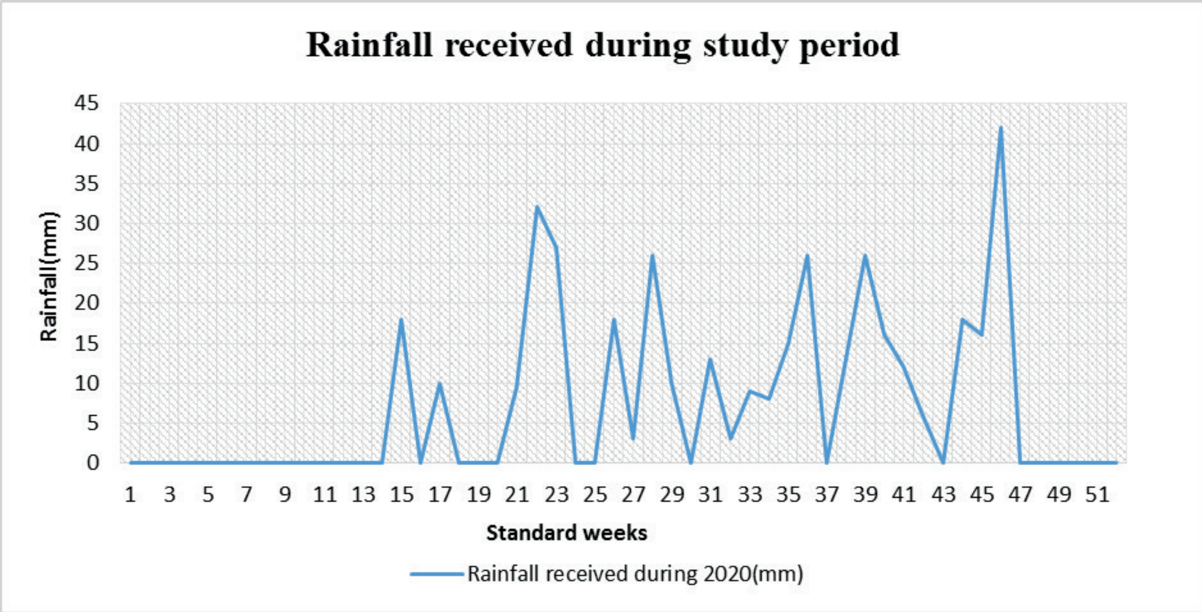

Fig. 3 -Rainfall receipt during the study period

were analysed with AGRES statistical software.

Software

The IRRI – Star software was used for rainfall analysis. The SMW based weekly rainfall was plotted against probability of rainfall

Results and discussion

Result of farmers' survey

The survey brought to light that, the farmers in this region had sown rain-dependent crops during 31st SMW (July 30 - August 5) and have a propensity to raise millets like sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*) little millet (*Panicum sumatrense*), finger millet (*Eleusine coracana*) under rainfed conditions which covers about 47.5% of the cultivated area (Fig 1) while the rest was occupied with crops like green gram (*Vigna radiata*), black gram (*Vigna mungo*), groundnut (*Arachis hypogea*), sesame (*Sesamum indicum*) and bengal gram (*Cicer arietinum*). This demonstrates the coping mechanisms followed by the farmers to change cropping pattern and choice of crops to have a stable income during aberrant weather conditions (Dhan foundation, 2020)

Rainfall analysis

The initial and conditional probability analysis of rainfall revealed that the length of the growing period in the study site is ranging between 32nd SMW and 42nd SMW and chances for occurrence of 20 mm rain per week start from 38th SMW until 52nd SMW, which is assured for successfully raising of crops during this period (Vanitha and Ravi Kumar, 2017). Yet again, with 80% probability of rains, it is guaranteed that the distribution of rainfall would be uniform throughout than at 50% probability of rainfall, which has minimum possibilities (Gupta *et al.*, 1975). Using IRRI star software for analysis of SMW based on weekly rainfall against the rainfall probability was represented in a box plot diagram (Fig.4). The rainfall probability box plot (Fig.4) indicated that the upper quartile was more than 55 percent and the lower quartile was approximately 18 percent. The median was fixed slightly towards the right side of the box midpoint indicating that only a few values were greater than the median, and the rest of the data were lower than that. Furthermore, it is understood from the figure that the median is not in the middle of the box, and the whiskers were not the same on both sides of the box, indicating the distribution may not be symmetric.

Influence of sowing window on growth and yield parameters

The biometric data recorded on growth parameters such as plant height, leaf area index, and dry matter production (DMP) at harvest were presented in Table 1, which revealed significant differences in growth parameters as influenced by different sowing windows in a rain-dependent condition. The tallest plants, higher leaf area index and maximum DMP were registered in sorghum when it was sown on 38th SMW (M3) at 75% probability of rainfall (i.e. calendar week, September, 17-23). This was due to the receipt of an adequate amount of rainfall starting from emergence of the plan-

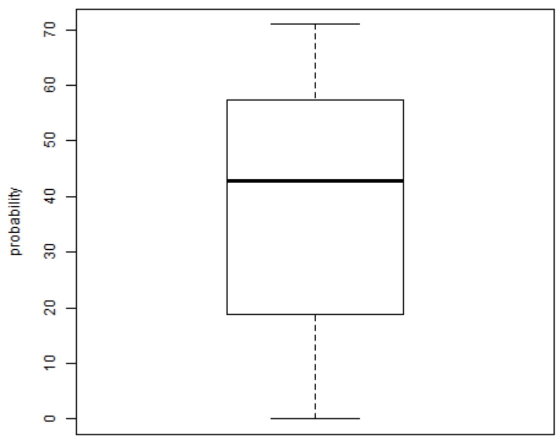

Fig. 4 -Standard meteorological weeks indicating the assured maximum rainfall weeks based rainfall probability analysis

tlet till maturity of the crop. The growth stages received regular rains such as sowing day (3mm), seedling (26mm), vegetative (34mm), flowering (18mm) and maturity (58mm) when compared to other sowing windows which supported the continued crop growth. The next best was to choose the current weather forecast at 35th SMW (M4) (i.e., calendar week, September 27-October 2). As regards little millet, sowing based on at 38th SMW (M3) at 75% probability of rainfall (i.e. calendar week- September, 17-23) was found to be the best time for sowing followed by sowing at 35th SMW (M4) (i.e. calendar week, September, 27 - October, 2) based on current weather forecast. Among treatment combinations, the reduction in plant height was noticed in little millet with sowing based on 33rd standard meteorological week (M2) at 50% probability of rainfall (August, 13-19). Kalhapure et al (2013) has reported that all the growth attributes of sorghum *viz.* height of plant, dry matter production and test weight were found significantly higher with sowing on 15th September in Maharashtra. Equally, Waghmare *et al.* (2010) has also accorded better growth and development of sorghum due to the favourable temperature, humidity, photoperiod and soil moisture condition when the crop was sown in early rabi season (October-November) at Parbhani, India. Grain yield and straw yield were recorded and presented in Table 2. A perusal of the data revealed that there was a significant increase in grain yield and straw yield when sorghum was sown at 38th SMW (M3) based on with 75% probability of rainfall (September 17-23) while the lowest grain and straw yields were recorded in little millet when sowing on 33rd SMW (M2) at 50% probability of rainfall (August, 13-19). The date of sowing is the critical and important factor that could decide the future of the crop performance under rain-dependent cropping. A team of workers *viz.*, Mokashi *et al.* (2008), Prasad *et al.* (2008), Bandiougou, (2012) and Vanderlip (2013), found that sowing date had a significant influence on grain sorghum through atmospheric flux in temperature and soil moisture availability at seed germination, vegetative and reproductive stages which ensured water availability from sowing to physiological maturity which increased yield and yield components. Kalhapure et al (2013) has specified that sowing of Rabi (winter) sorghum on 15th September produced higher seed and dry fodder yields and net return under a rainfed condition. Solaimalai et al (2017) found that among different dates of sowing tested, 39th standard week sown crop registered higher grain and stover yields in sorghum in Tamil Nadu, India.

Justification for fixing the best sowing window (38th SMW)

The sowing based on 38th SMW showed its mettle in terms of higher crop growth and yield, experienced adequate and well distributed rainfall throughout the cropping. Here, from sowing till harvest, about 157mm of rain was received with equal distribution. If we analyse the stages of crop growth vs. receipt of rains; for crop establishment up to 15 days, 45 mm of rain was received which ensured early crop establishment in the field and facilitated maximum plant population/m^2 (20 Nos.). Subsequently at the vegetative stage and flowering stage (between 16-60 days), a quantum of 112 mm was received at 50% rain during each stages of crop growth. This ensured healthier growth of the established crop in the vegetative phase that favoured sufficient flowering, which finally triggered very good filling of grain and maturity. Hence, sowing at 38th standard meteorological week could be adopted by the farmers of countryside, Coimbatore district, India, for raising both sorghum and little millet. A similar kind of study in Egypt by Omer (2005) showed that yield of the grain sorghum and dry matter increased with July and August sowing dates, compared to June, May and April sowing dates. Similar resulted were obtained by Conley and Wiebold, (2003), Assefa and Staggenborg, (2010) and Ayub *et al.* (2007), who reported that early sowing registered higher yields in sorghum than late sowings in three years of experimentation in Pakistan.

Conclusions

The study indicated that windows based on the SMW had significant influence on growth and yield parameters of the crops. The dryland farmers of Western agro-climatic zone of Tamil Nadu especially, Annur block can take up sowing of the rainfed crops like sorghum, little millet during September 17-23 i.e. 38th SMW sowing window to reap a good crop and profit in comparison to their existing practice.

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