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Short Communication

Rainfall variability and crop production in the North-western semi-arid zone of Nigeria

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This research work examined the implications of rainfall variability on some major food crops of the semi - arid region of northern Nigeria in a changing climate. Fifty years of daily rainfall data (1963 - 2012) were collected from the Meteorological unit of the Institute for Agricultural Research, Ahmadu Bello University Zaria and the data were processed using VISUAL-BASIC.NET programme. The concept developed by Ashok Raj (1979), "onset of effective monsoon and dry spells" was adopted in the present study. Grain yield data were also sourced from states' agricultural development projects. Correlation analysis was employed to assess the relationship between crop yield and dry spells. The result indicated about 10 days shift from the normal planting period. The result also showed negative relationship which is significant at 1% level of confidence for sorghum and maize and significant at 5% level of confidence for cowpea and rice. The smallholder farmers and policy makers were advised on the implications of the reduced and erratic rainfall pattern to agricultural productivity and science-based mitigation and adaptation strategies (such as water conservation techniques, genetic improvement of crops and improved irrigation techniques, water harvesting, etc.) were suggested.

Key words: Agriculture, evapotranspiration, rainfall, temperature, variability.

INTRODUCTION

Agricultural sector is one of the world's largest users and steward of natural resources. Like any productive activity, agricultural production exacts an environmental cost; the sector is one among many human activities contributing to the increased pressure on ecosystems and natural resources, such as land, air, water and biodiversity. At the same time, the sector is increasingly constrained by this pressure on natural resources and the growing competition with other sectors for resources. Climatic change in the combined effects of elevated temperatures and drought, with consequential increase in potential evapotranspiration, constitutes the greatest risk to agriculture in many regions (IPCC, 1990)

Increased human activities such as fossil fuel use, land-use change and agriculture have increased considerably; the amount of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) by 30, 45 and 15% have exacerbated the magnitude and pattern of global natural variability.

The current trend of highly variable weather events and

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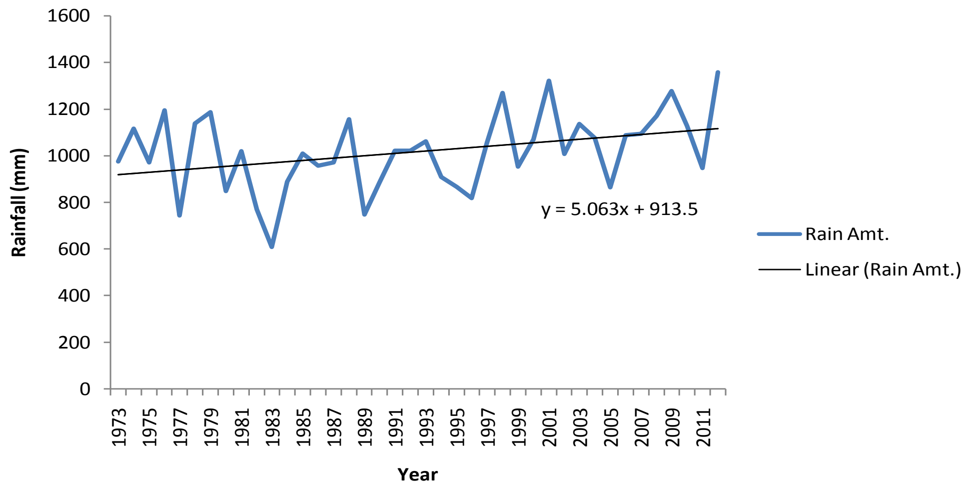

Figure 1. Time series analysis of rainfall for Samaru.

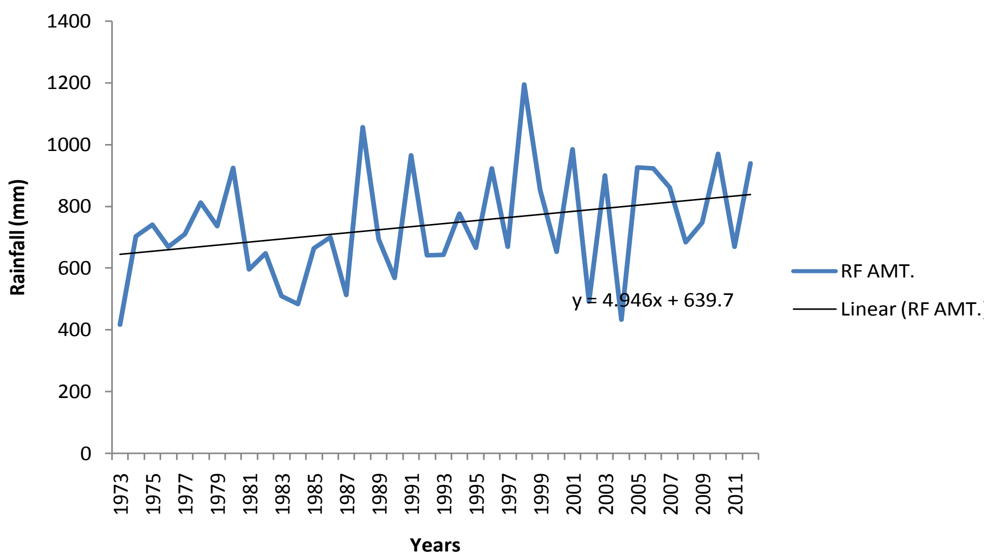

Figure 2. Time series analysis of Rainfall for Kano.

its effect on life in general and agriculture in particular, has made the study and understanding of weather events vital. Our ability to monitor and quantify weather variables has been limited by our ignorance and previous nonchalant attitude to weather variables. For us to help the poor farmers gain qualitative insight into their daily activities that will influence their daily bread in rural area, we need to first increase the awareness of workers for the poor. In most parts of the world, a detailed knowledge of the rainfall regime is an important pre-requisite for agricultural planning. Rainfall is undoubtedly the most limiting factor in crop production in north-west Nigeria where, currently, most crop production is derived from dry land farming. Hence the determination of rainfall amount, intensity and pattern is of great importance and should continue to receive priority attention especially in northern Nigeria. Rainfall records are analyzed to provide estimates of, for example, percentage points of rainfall totals or probability of dry spells. Estimates are usually derived using all available years of the record.

Rainfall variability and observed changes

There were evidences of high inter-annual variability of rainfall over the regions as shown in Figures 1 to 3. The high degree of this variability of rainfall is related to the randomness of the convective process, which is the dominant rain producing mechanism in the country. There was significant rainfall variability on monthly and

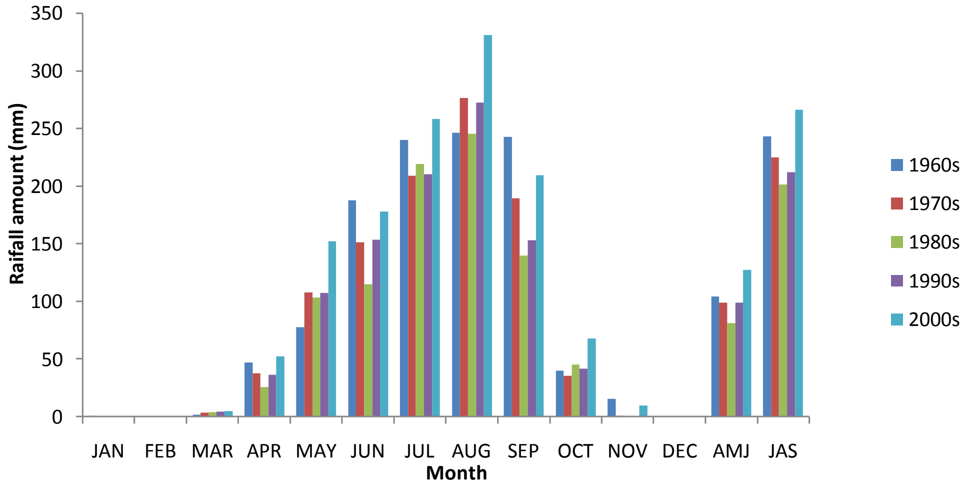

Figure 3. Decadal monthly and seasonal average of rainfall over Samaru.

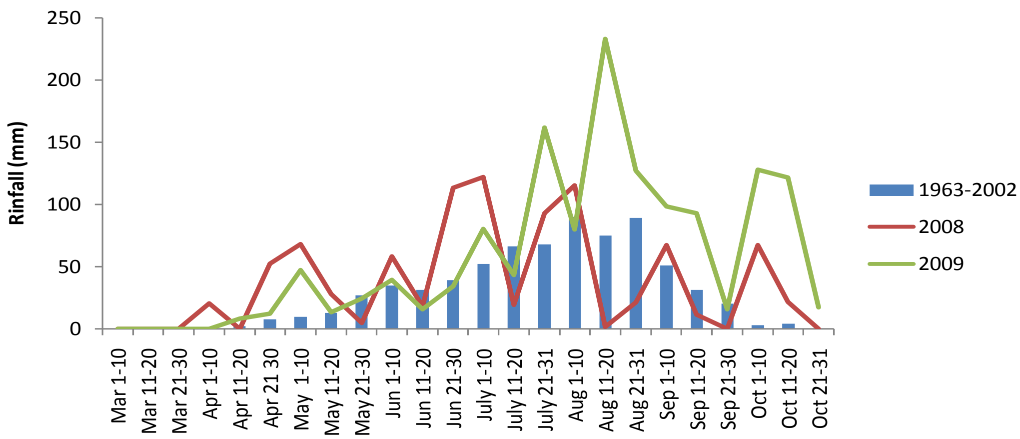

Figure 4. Decadal rainfall illustrating periods of dry spell in Samaru.

seasonal bases over Samaru in the last 50 years. In the first 40 years (1960 to 1990), the wettest years were recorded in the 60s followed by the next decade, then by poor early rains in the 80s. Conditions improved during the 90s followed by a total rainfall recovery in the 2000s. Most of the rain is however, observed to be concentrated within the months of July to September.

Although the rainfall amount is increasing above normal, the onset dates are always varying with backward shift in planting dates of up to 10 days in this ecological zone (Yamusa et al., 2013) and unpredictable incidence of early season dry spells thus affecting the length of growing season. If the present trends should continue, there would be greater effect of this variability on agricultural production. This is because pests and plant disease vectors are often arthropods, and their geographical distribution is determined by temperature, precipitation, relative humidity and the availability of host plants.

Justification and objectives of the study

Dry spell early in the season is a break in rainfall immediately after the first few rains. This period of significant rainfall deficit is more pronounced over the Northern Guinea Savanna ecological zone (Figure 4) and usually occurred between the first and the last decades of May while midseason spells occurs around June and July. The period of occurrence and duration keeps varying in recent times bringing about a backward shift and reduction in planting opportunities apparently induced by climate change. Early season dry spells affect soil water retention which would negatively impact on crop germination and establishment while the midseason spells effects is more pronounced on late maturing crop varieties. The comparative investigation of this phenomenon in the last five years indicated very pronounced early and mid - season dry spells especially in 2008 and 2011 as shown in Figures 4 and 5. This

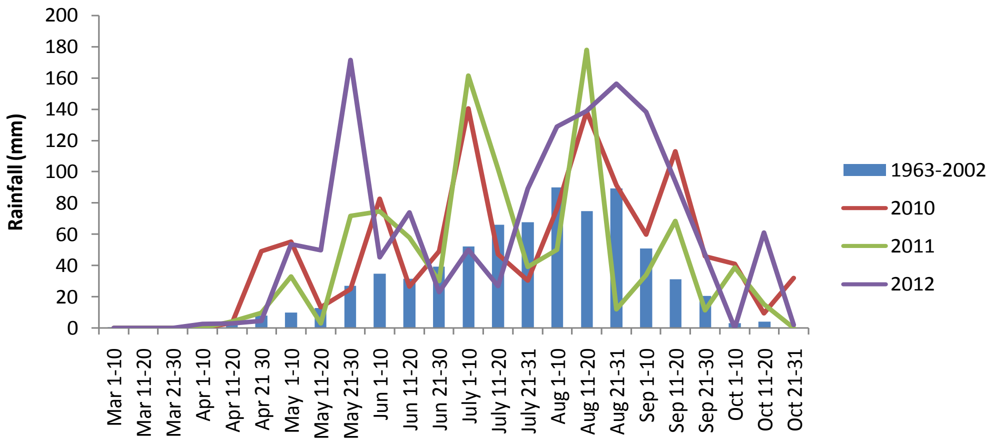

Figure 5. Decadal Rainfall illustrating periods of dry spell in Kano.

analysis informed the present study with the view to assessing the impact of climate change. Thus the work is aimed at evaluating the direct impact of the dry spell periods on grain yields as a result of rainfall variability and suggest mitigation option for policy makers as well as the smallholder farmer.

MATERIALS AND METHODS

Study area

The study area comprises of the seven Northwestern states of Nigeria which cut across the Northern Guinea Savanna Sudan Savanna ecological zones located within latitude 11°11'N, of the equator and longitude 7°38'E east of the Greenwich meridian. The study area, shares a common boundary with Niger Republic in the north, Bauchi and Yobe states in the east, Benin Republic in the west and Niger state in the south. Due to lack of reliable data in some parts of the zone, two stations (Samaru and Kano) were selected to represent the ecological zone.

The area has three distinct seasons; namely the hot dry season from March to May, the warm rainy season from June to September, and a cool dry season from November to February with a mean annual rainfall of about 1011±16.1 mm (CV=16%) from 1960 to 2003 (Oluwasemire and Alabi, 2004). The area has an average relative humidity of 36.0% during the dry season and 78.5% for the wet season. The average minimum and maximum temperatures recorded in the area are 15.6 and 38.5°C respectively (NCAT, 2008).

Daily rainfall data for the two stations were obtained from the Institute of Agricultural Research (IAR) data pool. These stations were chosen because of the availability of good and continuous rainfall records for a period of at least (40) years between the years (1963-2002). The daily rainfall amounts were summarized into monthly averages to examine the trend of rainfall for the years in Samaru and Kano.

Data analysis: Initial and conditional estimation of rainfall probabilities

In this study, daily rainfall data were processed using the VISUAL-BASIC (developed for the purpose) and INSTAT programme. Data analysis and the Markov chain probabilities based on daily basis adopted (Bekele, 2000). The Markov chain is defined as a stochastic process, in which the knowledge about the state of the process at a given time, t_2, can be deduced from the knowledge of its state at an earlier time t_1 and is independent of the history of the system before t_1 (Gabriel and Neumann, 1962).

Estimation of the initial and conditional probabilities of rainfall was done in two ways: The first was by using a written programme in VISUAL-BASIC with a module for precipitation occurrence, usually formulated as a Markov process. A simple point estimate for the probability of occurrence of a particular sequence of wet and dry days was given by Feyerherm et al. (1965) as the ratio of the number of years in which the sequence occurred to the number of years of record.

$$P_0(D_t) = \frac{no.of\ \ years\ \ that\ the\ (t)th\ day\ was\ dry}{no.of\ \ years\ of\ \ record} \tag{1}$$

Where $P_0(D_t)$ indicate the initial probability for the sequence of dry days. Other conditional probabilities could be estimated by similar ratios.

The second was estimated by the INSTAT+ 3.36 statistical package, is a simple general statistics package that also includes a range of special facilities to simplify the processing of climatic data. The expected amount of rainfall at specified probability levels were computed by fitting rainfall data with a complete Gamma distribution. This is a special case of Pearson type III distribution and has been found to fit rainfall data closely (Owonubi, 1992). The density function is given as:

$$g(x) = \frac{1x^{r-1}e^{-x/\beta}}{\beta^r\Gamma(r)} \quad \beta > 0 \tag{2}$$

Where x is a random variable (in this case rainfall amount). β is the scale parameter, **r** describe the shape of the distribution and Γ (r) the ordinary gamma function.

RESULTS AND DISCUSSION

From Figure 6 in Samaru, there are dry spells of 10 days

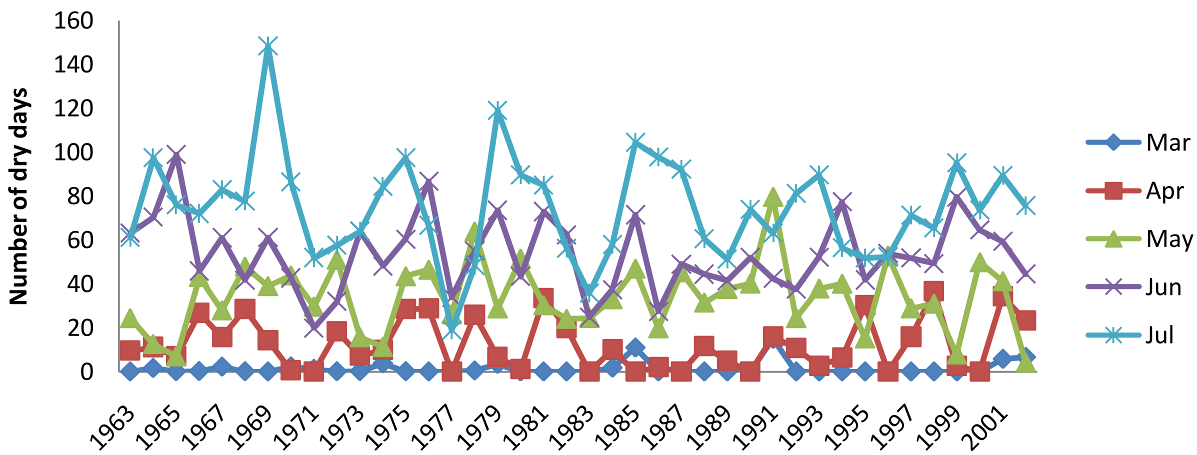

Figure 6. Number of dry spell day from March to July at Samaru.

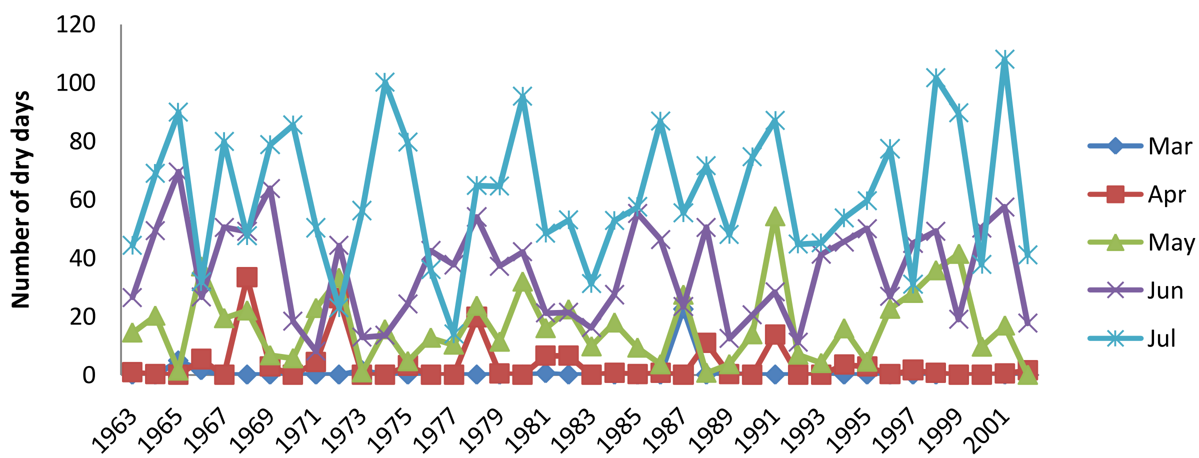

Figure 7. Number of dry spell day from March to July at Kano.

or more in 28 (70%) of the 40 years. In the subsequent 30 days (May) there are dry spells of 10 days or more in 10 (25%) of the 40 years. While the subsequent 60 days of the season (June and July) has only dry spells of 10 days or more in 4 (10%) and 2 (5%) of the 40 years. In Kano station, which is a more northern station, the rainfall is usually delayed and as expected, dry spells of 36 (90%) of the 40 years and 21 (52.5%) of the 40 years in the subsequent year (May) were recorded (Figure 7).

The longest spell in any year is 10 days except 8 and 6% of the years in June and July respectively. Assume that the sowing failed if there was a 10-day dry spell; in this case the farmers has to wait till June for successful sowing to avoid the risk of planting more than one time, because is estimated as 45 and 12% in May and June respectively. This agrees with the work of Kowal and Knabe (1972), Edoga (2007), Idris et al. (2011) and Idris et al. (2012) for suggesting the planting date to be June in the study area. But this work is suggesting the planting date should be from third weeks of May and June at the two stations of Samaru and Kano respectively to avoid the long dry spell periods.

Relationship between occurrences of dry spells and crop yield in the study area

There is strong correlation between occurrence of dry spells of various lengths and yield of some cereal crops at Samaru and Kano as observed by Sawa and Adebayo (2011). From the correlation matrix in Tables 1 and 2, it is evident that the occurrences of 7 day dry spell in June showed significant negative relationship with the yield of sorghum and cowpea in Samaru while in Kano the occurrences of 5 and 10 day dry spell showed significant negative relationship with the yield of cowpea and maize respectively. This is similar to the findings of Yayock and Owonubi (1986). In this ecological zone, the month of

Table 1. Correlation matrix of dry spell and crop yield at Samaru (after Sawa and Adebayo).

Day	Maize	Millet	Sorghum	G/nut	Cowpea
May 5	0.191	0.117	0.269	0.418	1
May 7	-0.192	-0.101	-0.393	-0.265	-0.026
May 10	-0.079	-0.077	-0.004	-0.106	-0.042
May ≥15	[a]	[a]	[a]	[a]	[a]
June 5	-0.072	-0.103	-0.293	-0.145	-0.154
June 7	-0.137	-0.225	-0.700**	-0.318	-0.366*
June 10	-0.001	0.174	0.101	-0.068	-0.174
June ≥ 15	[a]	[a]	[a]	[a]	[a]
July 5	-0.337	-0.089	0.186	-0.244	-0.183
July 7	-0.001	0.174	0.101	-0.068	-0.089
July 10	[a]	[a]	[a]	[a]	[a]
July ≥ 15	[a]	[a]	[a]	[a]	[a]

[a] Significant at 1 and 5% levels.

Table 2. Correlation matrix of dry spell and crop yield at Kano (after Sawa and Adebayo).

Day	Maize	Millet	Sorghum	G/nut	Cowpea
May 5	-0.342	0.090	0.422	0.145	-0.008
May 7	0.142	-0.550	-0.286	0.183	-0.203
May 10	0.075	0.049	0.042	-0.045	-0.434
May ≥ 15	-0.222	-0.059	-0.129	-0.098	0.352
June 5	-0.295	-0.068	0.463	0.027	-0.647*
June 7	0.191	0.306	0.169	0.257	0.300
June 10	-0.613*	-0.266	0.236	0.328	0.208
June ≥ 15	0.015	-0.121	-0.549	0.092	-0.375
July 5	0.161	-0.179	-0.164	0.387	0.019
July 7	-0.536	-0.483	0.189	-0.014	0.108
	[a]	[a]	[a]	[a]	[a]

[a] Significant at 1 and 5% levels.

June is a period for crop germination and establishment and therefore adequate rainfall is required for proper crop growth and development. This is why the occurrence of the dry spell at this stage impacted negatively on the yield of the crops.

Mitigation options and adaptation strategies (the role of IAR)

The Institute for Agricultural Research (IAR) is assiduously working on biodiesel crops such as Jatropha and Castor which are drought tolerant and can be used in marginal lands for mitigation of climate through carbon dioxide sequestration to mitigate the effect. The Institute which has the only irrigation research programme in the country is also researching on improving irrigation practices for improved water use efficiency, nutrient use efficiency, irrigation scheduling, cropping pattern and use of micro-irrigation facilities to ensure continuous food availability and affordability in a changing climate. A number of measures are also taken by the research programmes to adapt to the changing climate. Measures like genetic improvement and production of maize, cowpea, groundnut, cotton, sorghum, jatropha, artemisia, castor and sunflower are being taken. We have several high yielding, early, extra early, drought resistant, heat, diseases and pest tolerant crops that are adapted to changing climate. The farming systems and other research programmes of the Institute are employing system modeling in order to adapt to changes in climate that affect planting dates, harvesting dates and other farming operations. The agricultural mechanization research programme has developed technologies such as solar driers, threshers and millers that help in preservation and storage of farm produce during prolonged wet season to prevent losses. The meteorological unit of the Institute is well equipped and with a database from its inception in 1922 provides weather data from pre planting to post harvest period making it a service provider to the various programmes and departments of the Institute.

CONCLUSION AND RECOMMENDATION

This information regarding the period of occurrence of dry spells in a particular location is valuable in selecting crops and their varieties to obtain the required level of drought tolerance. Prior knowledge of dry and wet spells will also help in planning for the protective irrigations at appropriate times. It is concluded therefore that the effect of planting earlier than second week of June as a results of long dry spells of more than 8 days after planting would cause significant damage to shallow rooted crops and planting more than once. This work should therefore be extended to other parts of the country.

Conflict of Interest

The authors have not declared any conflict of interest.

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