DOI: http://doi.org/10.4038/tare.v20i1-2.5372

Tropical Agricultural Research & Extension 20 (1 & 2): 2017

THE RELATIONSHIP BETWEEN RAINFALL CHARACTERISTICS AND PROSO MILLET (*Panicum miliaceum* L.) CULTIVATION IN LOW COUNTRY DRY ZONE, SRI LANKA

EM Wimalasiri [1*], MJ Ashfold[2], S Walker[1, 3], SP Nissanka[4] and AS Karunaratne[5]

[1] School of Biosciences, Faculty of Science, University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor, Malaysia

[2] *School of Environmental and Geographical Sciences, Faculty of Science, University of Nottingham Malaysia Campus, Jalan Broga, 43500 Semenyih, Selangor, Malaysia*

[3] *Department of Soil, Crop and Climate Sciences, University of Free State, PO Box 339, Bloemfontein 9300, South Africa*

[4] *Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka*

[5] *Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, PO Box 02, Belihuloya 70140, Sri Lanka*

ABSTRACT

Proso millet (*Panicum miliaceum* L.) is a drought tolerant minor millet found in rainfed low input agricultural systems in Sri Lanka. This paper presents an analysis of characteristics of rainfall, of the onset, retreat and length of the '*Yala'* growing season (March-September) and the relationship between rainfall and crop husbandry strategies in a Proso millet growing area. Daily rainfall data (1983-2015) obtained from Udawalawa, Sewanagala, Pelwatta, Thanamalwila and Kuda Oya meteorological stations were analysed along with information gathered from a survey of farmers. Among these 5 stations significant ($p < 0.05$) differences were found in retreat date, the length of the season and rainfall amount during the season. It was observed that onset date can be used to predict the season length with high accuracy ($r = -0.7335$, significant at $p < 0.05$). The selection of crops and the timing of crop management practices in the Proso millet growing area coincided with the distribution of rainfall. However, the yields reported by farmers (mean 1.18 t ha^{-1}) are far below the expected potential (4 t ha^{-1}). Soil moisture conservation and water management strategies could be critical to reduce the risk of water-related damage in the susceptible flowering stage.

Key words: daily rainfall, onset, Proso millet, rainfed, *Yala*

INTRODUCTION

Proso millet (*Panicum miliaceum* L.), belonging to family Poaceae, is a crop with low water requirement (Baltensperger, 2002; Changmei and Dorothy, 2014) and has been highlighted as a crop that is particularly useful in a climate where rainfall might be less reliable (Swaminaidu *et al.,* 2015). It survives and gives yield under conditions with annual rainfall as little as 300 mm (Changmei and Dorothy, 2014). Excellent adaptability of this hardy crop to adverse effects of agro-climatic variations play an important role in agriculture in marginal areas, such as is commonly practised in hilly and semi-arid India (Ravi *et al.,* 2010). It is important that these hardy crops receive research attention because resilient agriculture is a good strategy to overcome the increased risk of droughts and monsoon-related inter annual rainfall variability in the Asian region (IPCC, 2014).

Proso millet is the principal crop in Low Country Dry Zone (LCDZ) in Sri Lanka during minor cultivation season (*Yala*). It is found in one of the primitive agricultural systems known as *Chena*, grown as a rainfed crop where minimum tillage conditions are used during the drier part of the year with low inputs (under shifting cultivation). As a result of the monsoons rainfall in Sri Lanka typically follows a distinctly bimodal pattern, leading to two cropping seasons. Especially in the Dry Zone (DZ), the principal or the major cultivation season (*Maha* - wet season) starts with Second Inter-Monsoon (SIM- October to November) and ends with the cessation of North

*Corresponding author: *emadushan@gmail.com*

weeks). During the study period, the rainy season averaged 58 days in DL_{1a} and 48 days in DL_{1b} AEZ. The length of the growing season decreased along the DL_{1a} to DL_{1b} AEZ (Table 3).

Proso millet requires 60-70 days to reach maturity so it will experience a dry period for 2-3 weeks before harvesting. Proso millet farmers prefer drier period at the latter stage of the crop because rainfall at this stage will cause seeds to shatter and plants to lodge. Higher rainfall during harvesting stage will interrupt the harvesting and postharvest handling practices, reducing both quantity and the quality of the Proso millet yield.

Thanamalwila recorded the shortest mean length of the season (Table 3). This was further complicated by the fact that onset at Thanamalwila was more variable than retreat and the higher SD for both onset and season length (Table 3). Therefore, timely land preparation and seed broadcasting are more critical in Thanamalwila.

A mean of 9.4% of onset events was not identified within *Yala* season across the study region because it did not occur within the defined time period (1st March - 1st May). In such cases, the years were identified as years with very late onset (Table 3). Each station except Udawalawa showed very late onset at least once and the highest number of these events were recorded from the driest part of the study region, namely Thanamalwila (20.83 %) and Kuda Oya (16.67 %) (Table 3). Proso millet farmers experienced a water shortage throughout the growing season in these stations suggesting the cultivation was at risk. Except for Pelwatta, all other very late onset events belonged to *Maha* (the second growing season) in the region.

Mann-Kendall trend analysis revealed that there was no significant ($p > 0.05$) long-term increasing or decreasing trends in the onset and retreat dates and length of the season at four stations except Thanamalwila during the period between 1983-2015 as onset showed a significantly decreasing trend at Thanamalwila ($p < 0.05$). Due to the observed increasing trend of growing season length at Thanamalwila and Kuda Oya, the stations with the shortest growing season length (45 and 47 days respectively) have a potential of supporting crop growth in the future in terms of length.

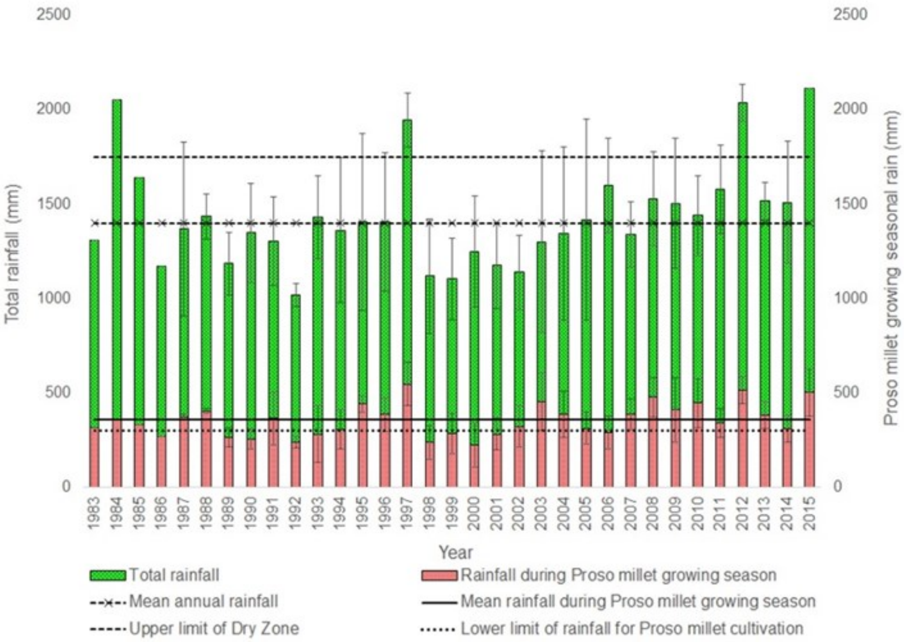

Figure 3: Interannual variability of rainfall, averaged over the 5 sites, in the Proso millet growing regions of Sri Lanka (1983-2015). Error bars represent the standard deviation of respective means. Mean annual rainfall (above) and mean rainfall during Proso millet growing season (below) are marked in vertical lines while dash (above) and dot (below) lines represent the upper limit of Dry Zone (Punyawardena 2008) and lower limit of rainfall for Proso millet cultivation (Changmei and Dorothy 2014).

The relationship between sowing and harvesting dates in Thanamalwila with rainfall distribution

Returning to information obtained from the farmer survey, reported sowing and harvesting frequencies are plotted along with daily rainfall amounts from Thanamalwila (the closest meteorological station - 6.5 km away from the centre of the survey area) and POWER in Figure 4. The results of t-test revealed that two rainfall data sets were not significantly different for 1st March - 30th June 2015 period ($p = 0.5223$) while significantly different ($p < 0.0001$) for complete data set (POWER data available for January 1997 - October 2015 period) at 95% probability level. Based on Thanamalwila data, onset and retreat of the 2015 *Yala* season were 3rd April and 17th May respectively, while for POWER data, they were 27th March and 15th June respectively.

Before starting the cultivation, farmers ask about rainfall events from other farmers who have fields away from the survey area or who have visited other areas. Discussions with farmers revealed that some localised rainfalls helped farmers to start the Proso millet cultivation, but they were not recorded at Thanamalwila meteorological station (Figure 4). Further, a total of 82% fields in the survey area was sown on the date of onset at Thanamawila. Therefore, the observed daily rainfall data at Thanamalwila does not in this case appear suitable for describing the farmer survey area, hence, POWER data was used for further analysis in this section.

The first sowing event was recorded on 23rd March in the survey area. Not all the farmers waited until the onset or a rainy day to start planting the crop as 4% sow Proso millet before the rains begin (on a dry day). Rest of the fields (96%) were sown after receiving 7 mm of rain. Among all, 22% of the fields were sown before the onset of the season (27th March). The highest percentage of sowing events (26%) was on the day following onset.

Table 3: Median dates for onset and retreat, mean length of the season and the earliest and most delayed onset and retreat and events with very late onset in Proso millet growing region in Sri Lanka.

Station	Median onset date	Standard deviation (days)	Earliest onset date	Most delayed onset date	Median retreat date	Standard deviation (days)	Earliest retreat date	Most delayed retreat date	Mean length of the season with SD (days)	Years with very late onset
Pelwatta (DL_{1a})	21-Mar	15	2-Mar	29-Apr	10-May	9	1-May	1-Jun	50±16	6.07 %
Udawalawa (DL_{1a})	14-Mar	12	2-Mar	8-Apr	25-May	15	1-May	3-Jul	66±23	0 %
Sewanagala (DL_{1b})	28-Mar	15	6-Mar	1-May	17-May	16	1-May	30-Jun	52±19	3.57 %
Thanamalwila (DL_{1b})	1-Apr	16	2-Mar	30-Apr	14-May	10	1-May	1-Jun	45±19	20.83 %
Kuda Oya (DL_{1b})	23-Mar	14	2-Mar	22-Apr	6-May	10	1-May	10-Jun	47±17	16.67 %

Some farmers (12%) broadcast seeds one week after the onset. In such cases, farmers reported a failure to clear lands due to rain, lack of labour and family problems (such as funerals) led to the delay in sowing seeds.

All the farmers harvested Proso millet within the rainy season (before the retreat day). The earliest harvesting (4%) was on 23rd May and the remaining fields were harvested within an 8-day period from 29th May. The length of the growing season (81 days) from POWER data for 2015 was longer than the mean length of 52 days across the region throughout the study period (1983-2015) while the length of year 2015 was 45 days. The length of growing season at Thanamalwila in 2015 was 44 days. Drier conditions during harvesting period are favourable for proper harvesting and post-harvest handling as described earlier. Results of the on-farm field survey revealed that labour availability is a big issue in the area, especially for harvesting. Because farmers use family labour for land preparation and sowing. Due to lack of labour, harvesting of Proso millet can be delayed by several days. In 2015, the harvest was damaged due to unexpected rain, but 64% farmers harvested their fields before receiving 10 mm of rain, the half of the amount for the onset. In such cases, farmers delay threshing and kept the harvest in the field as a heap covered using a polyethene to protect the grain. It was often observed that some matured fields or parts of them were left without harvesting due to rain and weeds.

Relationships of growing seasonal characteristics

Available evidence seems to suggest that there was a considerably higher correlation (r = -0.7335, significant at $p < 0.05$) between the onset and the length of the growing season than other relationships across Proso millet growing region in Sri Lanka (Figure 5) as the relationship was significant ($p < 0.05$) in all five stations. In most cases (65.8%), the length of the season is shorter than the Proso millet lifespan (60 days) suggesting that the crop experienced drought condition during reproductive and maturity stages. The length of the growing season at Udawalawa and Sewenagala exceeded 75 days on several occasions (47.8% and 14.8% respectively) when harvesting and postharvest handling of Proso millet could be affected by rainfall as happened during 2015 at Bodagama, Sri Lanka (Figure 4).

Other key information that would assist in agricultural planning is the relationship between onset and the amount of rainfall during a season. However, a poor correlation (r = -0.4799) was observed between the onset and seasonal rainfall in Proso millet growing region in

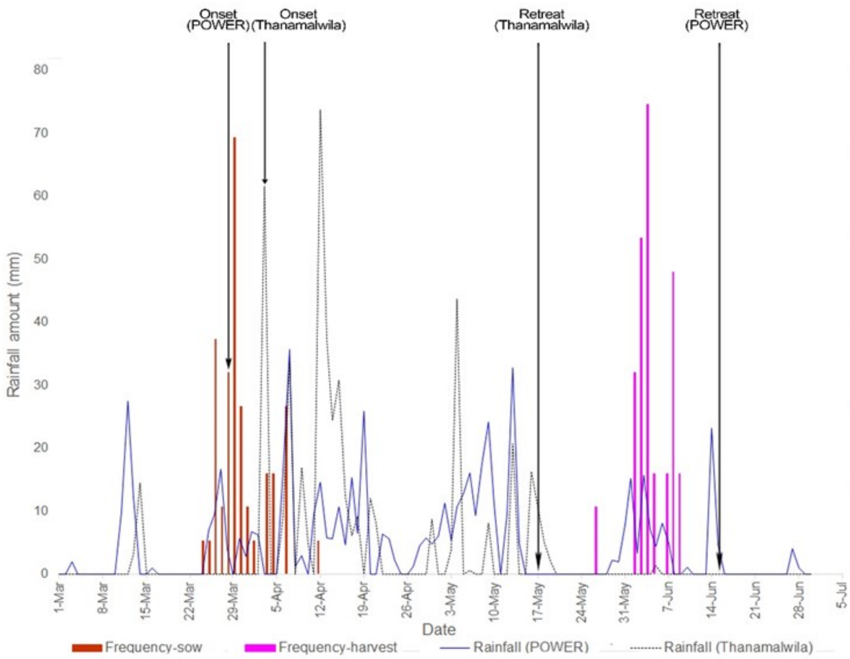

Figure 4: Farmers' sowing and harvesting dates of Proso millet and distribution of rainfall (POWER-straight blue line and Thanamalwila-dot line) in Bodagama, Sri Lanka during 2015 *Yala* season

LCDZ, Sri Lanka.

Dry spells during the growing season

The probability of 7-day dry spells in a period of 30 days during the Proso millet growing season followed a similar pattern in all the stations (Figure 5) but they were significantly ($p < 0.05$) different. The lowest probability of 7-day dry spell in Thanamalwila was from 22nd March to 29th March, during the data period. Interestingly, the on-farm field survey results revealed that mean and median Proso millet sowing dates for 2015 were 29th March and 28th March respectively. It was recorded that Proso millet farmers in the area select the day with the lowest probability of potentially damaging dry spell to sow seeds that will reduce seed desiccation and increase plant emergence. It comes from their experience and none of the farmers check the water availability by testing soil moisture in the field in to a certain depth.

Proso millet fields near Thanamalwila and Kuda Oya experience a higher probability (98% and 97% respectively) of 7-day dry spells at flowering stage, but the probability was comparatively lower in other stations. The risk of 7-day dry spells was lower during the initial crop growth phases but increased with the age. Proso millet plants at reproductive and ripening stages are more vulnerable to long-term dry spells.

Both seeds and seedlings of Proso millet can be damaged due to heavy rain and drought during the initial phases of the crop, causing uneven crop stand across the field or permanent loss of the crop. Proso millets fields are never re-sown to fill the gaps and farmers maintain and harvest the remaining parts of the field. The strategy used by farmers to protect against unexpected damages was to maintain a high plant density, as described in earlier. The amount and favourable distribution of rainfall during Proso millet growing period are key factors for a successful cultivation.

Rainfall amount and distribution determines the lifestyle of subsistence farmers in agricultural areas in Sri Lanka. All the farming activities in the Proso millet growing area were found to be heavily depended on the amount and the distribution of rainfall which agrees with the findings of Gunarathna *et al.,* (2004).

Previous work on growing seasonal characteristics of the LCDZ in the southern plains of Sri Lanka was almost non-existence, therefore this analysis can be used to make recommendations for farmers in those areas. Previous studies of Punyawadena (2002) recorded that onset and retreat of *Yala* season in the North Cen-

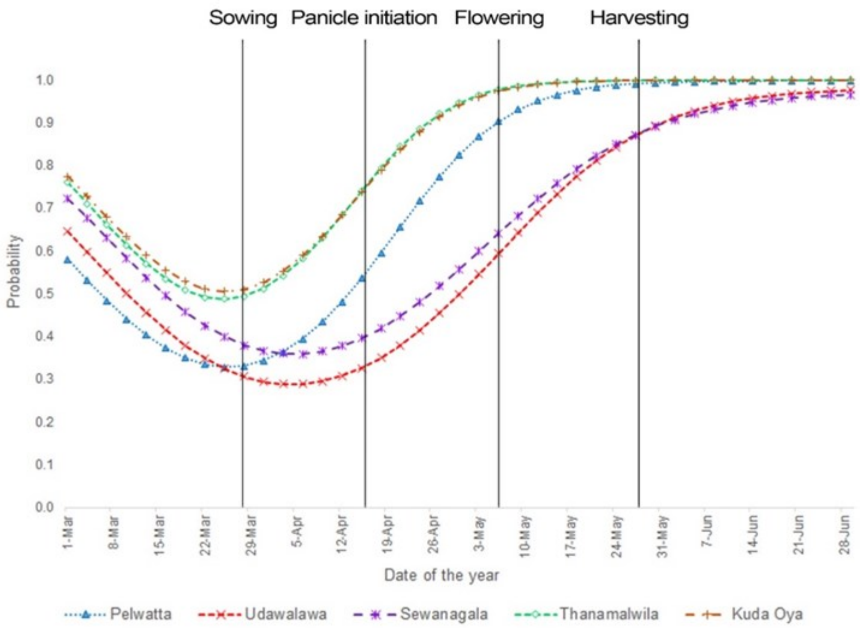

Figure 5: The probability of 7 days dry spells in a period of 30 days centred on a particular day during the Proso millet growing season in Low Country Dry Zone Sri Lanka for 1983-2015 period. All the dates marked in this figure are based on information from the farmer survey.

tral Dry Zone that belongs to the DL_{1b} AEZ were in late March (13th week) and in late April (between 18th-19th week) respectively. Observed mean onset (12th week) and retreat (20th week) in the Proso millet growing region were different to the findings of Punyawadena (2002) by one week. The mean of 7.4 -week length of growing season across Proso millet growing area was much higher than the 5-week period reported by Punyawadena (2002).

Sri Lankan climate is divided into two cultivation seasons by different timescales as identified in different studies (Zubair 2002; De Silva *et al* 2007; Chithranayana and Punyawardena 2008; Sonnadara 2015). However, we found the actual growing season that supports crop cultivation is far below the hypothetical growing season reported in most studies. Rainfall retreat 11-15 weeks before the generally accepted end to growing season (*Yala*) defined in the literature. Southwest Monsoon is not clearly observed in the area (Punyawardena 2008) and creates water scarcity during the latter part of *Yala* that limits the options for crop cultivation in the Proso millet growing region in June onward.

Since the first rain event is not always followed by the onset of the rainy season in the area (Figure 4), dry spells could occur during early stages of the crop growth. Therefore, it is worth to distinguish the dry spell to avoid the false onset when identifying the best sowing date. Marteau *et al.,* (2011) investigated the relationship of rainfall onset and farmers' sowing strategy for Pearl millet cultivation in Southwest Niger, finding that most farmers waited for the first rain event before sowing whereas a few of them sow seeds before the rains, i.e. when the soil is dry. This is called 'dry seeding' and allowed farmers to get more arable lands sown at the time of onset and reduce time-consuming land preparation after the first useful rain. On the other hand, this technique has a higher possibility of having poor plant establishment due to damage caused by insects, birds, and seed desiccation (Liboon *et al.,* 2001).

Some other Proso millet farmers avoid seeding at the onset of the rainy season to protect seeds from heavy rain. The inability to sow in a rainy day, with farmers reporting this could be due to delay in land preparation, or social and religious activities, lead to dry seeding of Proso millet. But, the dry seeding is not a farming technique followed by Proso millet farmers in Sri Lanka as an adaptation strategy to rainfall variability and to the labour shortage, such as commonly practised in Niger (Marteau *et al.,* 2011). The date of seed broadcasting varied within a couple of weeks in the same area, but discussions with farmers and survey results revealed that the sowing date solely depends on rainfall. Therefore, any changes in the onset of the rainy season will affect the Proso millet cultivation in the area.

Different crop growth stages are sensitive to water availability in different ways. In Proso millet, the greatest reduction of water use efficiency (32.0 % to 36.4%) was reported during the ear emergence stage (Seghatoleslami *et al.,* 2008). Further, these authors reported that floret death and lowering of seed weight that reduces the harvest index are the major impacts caused by the drought stress at ear emergence stage. Avoidance of moisture stress at ear emergence and flowering by the possible shift of the sowing date to a later date is limited by variation in the onset date because false onset can damage the crop in early stages. The higher probability of long term dry spells during the reproductive stage (Figure 5) that limits water availability in the most sensitive growth stage can be the reason for the lower yield recorded in yield analysis.

Delayed onset of rainfall is one of the major climate related agricultural issues that responsible for abnormal cropping calendar, crop failure and yield reduction in Intermediate Zone (IZ), Sri Lanka (Esham and Garforth, 2013). Change in planting dates, changing crop varieties and crop rotation are the most prevalent adaptation strategies practised in Mid Country Sri Lanka to bypass the critical crop growth stages from overlapping dry periods (Esham and Garforth, 2013). The comparatively shorter length of the growing season than that which occurs in the Wet and IZ, low water availability and high variability of rainfall in the area (Punyawardena, 2002) limit the usage of these management practices in Proso millet growing region in Sri Lanka. Changing planting date is a no cost adaptation strategy that can be implemented at the farm level, but large shifts would affect the management of other crops grown during rest of the year (Mall *et al.,* 2006). Proso millet cultivation in year 2015 experienced a higher probability of 7-day dry spells (98% at Thanamalwila) during the flowering stage (Figure 5). Delayed planting of Proso millet makes the plants more susceptible for dry spells from the vegetative growth stages. Furthermore, changes in cropping sequence and land use can be used as an alternative adaptation option under the changing rainfall pattern. In some regions, low availability of land areas limits the possibility of shifting Proso millet cropping fields, as it is most common in the *Chena* farming systems.

Rainwater harvesting, improvement of soil, water and nutrient holding capacity and soil conservation were not practised in Proso millet fields. Due to the short rainy season in some areas, it is important to invest in soil, water and nutrient management technologies for Proso millet cropping systems. But most of the Proso millet farmers are practising shifting cultivation inside the small forest areas and therefore, it limits the possibilities of introducing new technology.

It is important to identify the vulnerability to climate change in the region and suitable adaptation strategies. Research should be encouraged to identify and develop crop varieties that can sustain good yields under the changing climate conditions. Further, research attention is required on seed/plant densities, soil improvement and management practices that increase the yield. Modern agricultural technologies should be introduced to low input agricultural systems in the region.

CONCLUSION

The selection of crops and crop management practices in the Proso millet growing area in Sri Lanka coincided with the distribution of rainfall. The mean rainfall during the Proso millet growing season throughout the study period (361 mm) is higher than the lower limit of rainfall (300 mm) where Proso millet gives a satisfactory yield, based on the literature. But, the yields reported by farmers (ranged from 0.470 to 1.956 t ha^{-1}) are far below the potential value (4 t ha^{-1}). Date of onset was not significantly different among stations and can be successfully used to predict the length of the season in Proso millet growing region in Sri Lanka. Implementation of soil moisture conservation and water management practices are critical for a successful Proso millet cultivation in Low Country Dry Zone Sri Lanka.

ACKNOWLEDGEMENT

Authors thank to Sugarcane Research Institute (SRI), Department of Irrigation Sri Lanka and Lanka Sugar Company Ltd. for providing observed daily precipitation data. We are also grateful to the financial supports of The University Gants Commission Sri Lanka (UGC), Crops For the Future, Malaysia (CFF), University of Nottingham Malaysia Campus (UNMC) and Sabaragamuwa University of Sri Lanka (SUSL).

REFERENCES

Aviad Y, Kutiel H and Lavee H 2004 Analysis of beginning, end and length of the rainy season along a Mediterranean arid climate transect for geomorphic purposes. J. Arid Environ. 59:189-204.

Changmei S and Dorothy J 2014 Millet-the frugal grain. *Int. J. Sci. Res. Rev.* 3:75-90.

Chithranayana RD and Punyawardena BVR 2008 Identification of drought prone agro-ecological regions in Sri Lanka. J. Natl. Sci. Found Sri Lanka. 36(2):117-123.

De Silva CS, Weatherhead EB, Knox JW and Rodriguez-Diaz JA 2007 Predicting the impacts of climate change. A case study of paddy irrigation water requirements in Sri Lanka. Agric. Water Manag. 93:19-29.

Esham M and Garforth C 2013 Agricultural adaptation to climate change: Insights from a farming community in Sri Lanka. Mitig. Adapt. Strategies Glob. Change. 18:535-549.

Gunarathna MHJP, Navaratne M and Weerasinghe KDN 2004 Effect of rainfall on cropping pattern of farmers in Hambantota District. pp 49-54. In: Second Academic Sessions. Sri Lanka: Univ. Ruhuna, Sri Lanka.

IPCC. 2014: Summary for policymakers. In: Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field CB, Barros VR, Dokken DJ, Mach KL, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC and *et al* (eds). World Meteorological Organisation, Switzerland. pp. 22.

Kendall MG 1975 Rank Correlation Methods. 4th ed. Charles Griffin, London.

Liboon SP, Abrogena NQ, Aguinaldo A, Castro R and Sebastian LS 2001 Modified dry-seeding with zero tillage & straw mulching: A new technology package for rain fed rice. Philipp. J. Crop Sci. 26(2):5-13.

Mann HB 1945 Non parametric test against trend. Econometrica. 13:245-259.

Marteau R, Sultan B, Moron V, Alhassane A, Baron C and Traore SB 2011 The onset of the rainy season and farmers' sowing strategy for Pearl millet cultivation in Southwest Niger. Agric. For. Meteorol. 151(10):1356-1369.

Mavi HS and Tupper GJ 2004 Agrometeorology: Principles and Application of Climate Studies in Agriculture, Food Products Press, New York. pp. 70-71.

Mupangwa W, Walker S and Twomlow S 2011 Start, end and dry spells of the growing season in semi-arid southern Zimbabwe. J. Arid Environ. 75:1097-1104.

Omotosho JB, Balogun AA and Ogunjobi K 2000 Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. Int. J. Climatol. 20:865-880.

Punyawardena BVR 2002 Identification of the potential of growing seasons by the onset of seasonal rains: A Study in the DL_1 region of the North Central Dry Zone. J. Natl. Sci. Found Sri Lanka. 30(1&2):13-21.

Punyawardena BVR 2008 Precipitation of Sri Lanka and agro-ecological regions. Sri Lanka: Agriculture Press.

Ravi SB, Swain S, Sengotuvel D and Parida NR 2010 Promoting nutritious millets for enhancing income and improved nutrition: A case study from Tamil Nadu and Orissa. pp. 19-46. In: Mal B, Padulosi S and Ravi SB (eds.) Minor millets in South Asia. India: Biodiversity International, Maccarese, Rome, Italy and the M.S. Swaminathan Research Foundation.

Seghatoleslami MJ, Kafi M and Majidi E 2008 Effect of deficit irrigation on yield , WUE and some morphological and phenological traits of three millet species. Pak. J. Bot. 40 (4):1555-1560.

Stern R, Knock J, Rijks D and Dale I 2003 INSTAT Climatic Guide: The University of Reading; [cited 2015 Sep 25]. Available from http://www.reading.ac.uk/ssc/software/instat/climatic.pdf

Suppiah R 1996 Spatial and temporal variations in the relationships between the Southern Oscillation phenomenon and the rainfall of Sri Lanka. Int. J. Climatol. 16:1391-1407.

Swaminaidu N, Ghosh SK and Mallikarjuna K 2015 Millets: The Miracle Grains. Int. J. Pharm. Bio Sci. 6(4):440-446.

Zhang T, Chandler WS, Hoell JM, Westberg D, Whitlock CH and Stackhouse PW 2007 A Global Perspective on Renewable Energy Resources: NASA's Prediction of Worldwide Energy Resources (Power) Project. In: Proceedings of ISES World Congress. 9(I-V): 2636-3264.

Zubair L 2002 El Niño-Southern Oscillation influences on rice production in Sri Lanka. Int. J. Climatol. 22:249-260.