Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

December 2021, Volume 34, Issue 2, Page 153-158

Effect of temperature and rainfall on ginger production in Meghalaya

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ARTICLE INFO

Article history:
Received: 17 November, 2021
Revision: 15 December, 2021
Accepted: 29 December 2021

Key words: Climate change, linear trend, ginger, Meghalaya.

ABSTRACT

Ginger, one of the important cash crops, is cultivated as rainfed crop in Meghalaya. The production of ginger depends on climatic variables like rainfall and temperature. A significant declining trend in monthly rainfall during critical stages of ginger growing period was observed during the study period. This study also attempts to estimate the effect of change in rainfall and temperature on ginger production in Meghalaya by using log-linear regression model. The estimated regression coefficients revealed that average minimum and maximum temperatures positively influence the ginger production in Meghalaya. One per cent increase in minimum and maximum temperature leads to 4.74 per cent and 5.913 per cent increase in production of ginger. The study revealed that quantum of June rainfall (0.284%) has positive effect on the production of ginger whereas, October (-0.126%) and November (-0.050%) rainfalls negatively influence ginger production in Meghalaya.

1. Introduction

Ginger is an important spice crop. The underground rhizome is the economic part of the crop which is pungent and aromatic. The crop is traded in three basic forms viz., fresh ginger rhizome, pickled or preserved ginger and dry ginger. Only the dried ginger is considered as spice, fresh ginger is regarded as vegetables. The dried ginger or ginger powder is also used in wine manufacturing industries other than its consumption as spice. Ginger oil is used as flavoring agent in soft drinks. Ginger has high nutritional and medicinal property. Fresh ginger contains 12.3% carbohydrate, 2.3% protein, 0.9% fat and small amount of vitamins and minerals. The dried ginger contains 12% moisture, 15% volatile oil and 6% oleoresin (Khatiwada *et al*., 2017). In India, the total area under ginger is 175.24 thousand ha with a total production of 1876.05 thousand tonne during 2019-20 (GoI, 2020). The area under ginger was highest in Karnataka (23.09 thousand ha) followed by Assam (18.79 thousand ha) and Odisha (16.57 thousand ha) during 2017-18 (GoI, 2018). In case of North Eastern (NE) states of India, Meghalaya has the highest area under ginger after Assam. The total area under ginger in Meghalaya is 9940 ha with a total productivity of 6660 kg/ha during 2017 (GoM, 2018). The productivity of ginger in Meghalaya was slightly lower than the all India average productivity (6982 kg/ha) during 2017-18 (GoI, 2020).

In Meghalaya, ginger is sown in the month of April–May and harvested during December (Mawlong, 2017). The crop is mostly grown as rainfed crop in Meghalaya and thrives well in light soil, rich in organic matter (Yadev *et al*., 2018). Ginger requires 1300-1500 mm of water during the whole crop cycle. The critical stages of crop water requirement are germination, rhizome initiation (90 days after planting) and rhizome development (135 days after planting) (www.vikaspedia.in). During seedling stage (April-May), due to slow growth and less growth of biomass, the plant required less water but it cannot endure drought. If water requirement is not met during this stage, the leaves of the plant develop 'roll up pigtail' symptom, and yield reduces due to weak photosynthesis. During active growing stage (June-July to August-September), biomass growth also increases and the plant requires more water. The soil should

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be moist and the relative water content should be maintained at 70 to 80 per cent (Kun, 1999).

The crop grows well in warm and moist climate, in areas with temperature between 20°C to 30°C but it can thrive up to 35°C. Xizhen *et al.* (1998) reported that the most favorable temperature for germination of ginger is 22°C to 25°C. Germination is quick when the temperature goes above 30°C but the sprouts are weak. When temperature falls below 20°C, ginger can germinate but it is slow. During the seedling stage and early growing stage, the suitable temperature is 22°C to 28°C. The favorable temperature during rhizome development stage is 25°C (Xizhen *et al.*, 1998). Yadev *et al.*, 2018 also revealed that in Meghalaya, the crop does not grow well in high temperature exceeding 32°C with low relative humidity.

The changes in climatic variables have the potential to affect ginger production. Meghalaya is also experiencing change in climatic conditions over the period. The state experienced late arrival and early withdrawal of monsoon. Moreover, the traditional wet districts of Meghalaya viz., East Khasi Hills, Jaintia Hills and Ri-Bhoi have experienced reduced degree of wetness during 1991 to 2007 (Saikia *et al.*, 2013). Hence, this paper tried to find out the effect of change in climatic variables on ginger production in Meghalaya.

2. Methodology

Secondary data on daily rainfall and daily temperature for thirty-four years (1984-2017) were extracted from high resolution $0.25^0 \times 0.25^0$ and $1^0 \times 1^0$ daily gridded data, respectively obtained from India Meteorological Department (IMD), Pune. For the present study, 8 rainfall stations and 2 temperature stations which were between 90.5^0E to 92.25^0E longitude and 25.5^0N latitude were considered. The rainfall stations fall in the districts namely, East Garo Hills, South Garo Hills, West Garo Hills, East Khasi hills, West Jaintia Hills and the temperature stations fall in East Garo Hills and West Khasi Hills. The individual station data were used to arrive at state average. The secondary data on production of ginger (1984-2017) was collected from the Directorate of Economics and Statistics, Government of Meghalaya to estimate the effect of rainfall on production of ginger.

Ordinary Least Squares (OLS) method was used to determine the effect of rainfall and temperature on production of ginger. In the OLS method, production of ginger was regressed on monthly rainfall (April, May, June, July, August, September, October, November and December) and annual minimum and maximum temperature. Log-linear regression model was used for the present study. Similar regression model was used by earlier researchers (Brithal *et al.*, 2014; Dkhar *et al.*, 2017; Feroze *et al.*, 2021)) to study the impact of climate change on crop yield or production.

Log-linear regression model:

$$\log Y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + b_4 \log x_4 + b_5 \log x_5 + b_6 \log x_6 + b_7 \log x_7 + b_8 \log x_8 + b_9 \log x_9 + b_{10} \log x_{10} + b_{11} \log x_{11} + e$$

Where, Y = Production of ginger (MT); a = intercept; b_1, b_2, b_3, b_4,b_5 , b_6 , b_7 , b_8 , b_9 , b_{10} and b_{11} are the regression coefficients; x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10} and x_{11} are the monthly rainfall during April, May, June, July, August, September, October, November and December and annual maximum and minimum temperature, respectively and e = residual of regression.

3. Results and Discussion

Trend in climatic factors in Meghalaya

In Meghalaya, the monthly rainfall of ginger growing months (April-December) was highest in the month of July (965.78 mm) which contributed 23.50 per cent of the total annual rainfall (Table 1). The July month was followed by June (852.55 mm), August (653.97 mm), September (459.14 mm) and May (452.73 mm). The average monthly rainfall was lowest in December (10.30 mm) followed by November (37.03 mm). A minimum average monthly rainfall of near zero was registered in the month of November (0.10 mm in the year 2012) and December (0.03mm in the year 1998) while maximum average monthly rainfall was observed in the month of July (1999.44 mm in the year 2015), followed by June (1941.16 mm in the year 1987) and August (1701.51 mm in the year 2015) during 1984-2017 in Meghalaya (Table 1).

The coefficient of variation (CV) for monthly rainfall were high during the critical stages of ginger (germination, rhizome initiation and rhizome development). This critical stages fall in the month of April-May, June-July and August-September, respectively. The CV during this period ranged between 45.19% (May) and 63.29% (April) indicating high rainfall variability during these critical months. Furthermore, there was significant declining linear trend in average monthly rainfall in the month of May (β = -6.37). The trend coefficient indicated a decline in monthly rainfall at the rate of 6.37 mm annually in May. Likewise, there was significant declining trend in average monthly rainfall in July (β = -25.93), September (β = -10.27), October (β = -7.24), November (β = -2.50) and December (β = -0.43). The high CV value in addition to significant declining trend in monthly rainfall during critical ginger growing months is a cause of concern for ginger growers since the crop is grown as rainfed crop in the state.

The average annual maximum temperature in the state was 28.17°C with the lowest of 27.42°C (1992) and the highest of 29.07°C (2016). The average annual minimum temperature in the state was 18.33°C with the lowest of 17.54°C observe in 1992 and the highest of 19.10°C registered

in 1998 (Table 1). In Meghalaya, both annual maximum (β = 0.03) and minimum (β = 0.02) temperatures have shown significant increasing linear trends during 1984-2017. The annual maximum and minimum temperature increased at the rate of 0.03°C and 0.02°C annually (Table 1 and Fig 2).

Effect of rainfall and temperature on production of ginger

In Meghalaya, the average annual production of ginger is 47105.59 MT. The production ranged between 26000 MT (the year 1986) to 66370 MT (the year 2016) with high inter year variability (Fig 3). The results of Log-linear model (Table 2) showed that the quantum of rainfall in June have positive significant influence on production of ginger ($p<0.01$). On the other hand, October ($p<0.01$) and November ($p<0.01$) rainfall have negative influence on yield of ginger. The model indicated that 1% increase in June rainfall leads to 0.284% increase in production of ginger while, 1% increase in October and November rainfall leads to 0.126% and 0.050% decline in production of ginger, respectively. Okwuowulu (2005) reported that ginger is sensitive to water logging condition therefore, when the crop is at maturity stage *i.e.*, prior to harvesting, rainfall is detrimental for the crop. Table 2 also reveal that the minimum and maximum temperatures positively ($p<0.05$) influence production of ginger in Meghalaya. One per cent increase in minimum and maximum temperature leads to 4.745% and 5.913% increase in production of ginger, respectively.

4. Conclusion

Temperature and rainfall are the two important parameters of ginger production. The annual minimum temperature ranged between 17.54°C and 19.10°C while the annual maximum temperature ranged between 27.42°C and 29.07°C during the study period. There was significant increasing trend in minimum and maximum temperature. The temperature condition in the state is suitable for growth and development of ginger crop as the regression model also showed that with increase in temperature, the production of ginger also increased. The study revealed that June rainfall had positive and significant effect on production of ginger but rainfall during this month was erratic, ranging between 214.54 mm to 1941.16 mm. There was significant declining trend in monthly rainfall during active growing period of ginger. The inter year variability of monthly rainfall during critical growing period of ginger was also high. As ginger is grown as rainfed crop in Meghalaya, the changing rainfall pattern is a cause of concern for the farmers.

5. Acknowledgements

The paper is derived from the ICSSR funded project entitled **"**Spice based rural economy and livelihood under climate change in Himalayan region of India: Economics of adaptation measures". We acknowledge ICSSR, New Delhi for funding the project.

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Table 1. Descriptive statistics of the variables used in regression model

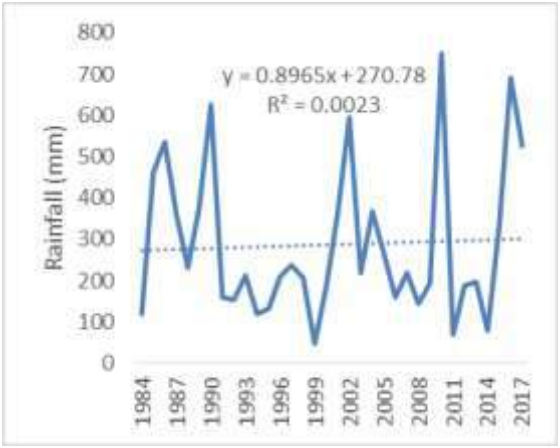
Particular	Average	Maximum	Minimum	CV (%)	Trend coefficient
Production (MT)	47105.59	66370	26000	25.18	1160.77***
April rainfall (mm)	276.26	749.15	48.66	63.29	0.90
May rainfall (mm)	452.73	1244.30	118.00	45.19	-6.37*
June rainfall (mm)	852.55	1941.16	214.54	47.41	-6.70
July rainfall (mm)	965.78	1999.44	170.71	49.03	-25.93***
August rainfall (mm)	653.97	1701.51	164.61	56.94	-1.12
September rainfall (mm)	459.14	1209.06	139.03	54.53	-10.27**
October rainfall (mm)	254.97	865.44	19.60	69.02	-7.24**
November rainfall (mm)	37.03	218.73	0.10	152.28	-2.50**
December rainfall (mm)	10.30	56.99	0.03	137.17	-0.43**
Minimum Temperature (^{o}C)	18.33	17.54	19.10	-	0.02***
Maximum Temperature (^{o}C)	28.17	27.42	29.07	-	0.03***

*, ** and *** represents p<0.1 p<0.05, p< 0.01, respectively

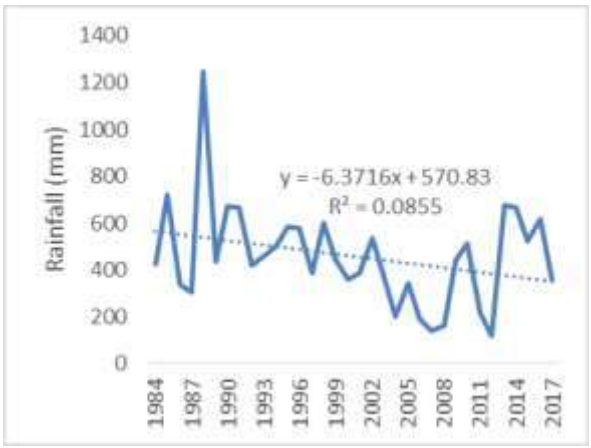
Table 2. Estimated co-efficient of Log-linear model

Variables	Coefficient	p-value	Standard Error
Constant	−22.476***	0.002	6.547
April rainfall	0.036	0.491	0.053
May rainfall	−0.071	0.327	0.071
June rainfall	0.284***	0.004	0.090
July rainfall	−0.076	0.260	0.066
August rainfall	−0.118	0.123	0.074
September rainfall	0.010	0.905	0.084
October rainfall	−0.126***	0.003	0.038
November rainfall	−0.050***	0.003	0.015
December rainfall	−0.007	0.631	0.015
Minimum Temperature	4.745**	0.015	1.802
Maximum Temperature	5.913**	0.021	2.378
R-square	0.80		
Akaike criterion	-23.805		

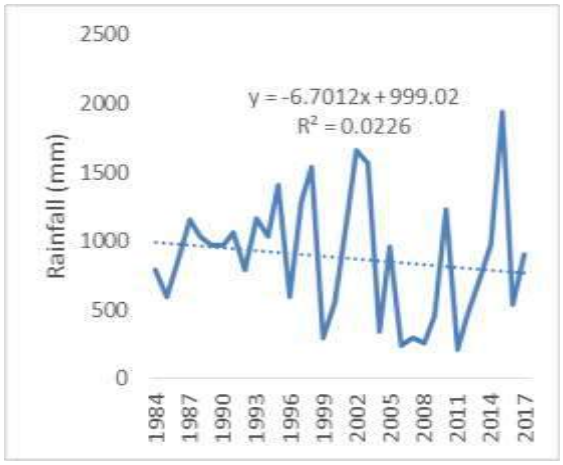
** and *** represents p<0.05, p< 0.01, respectively



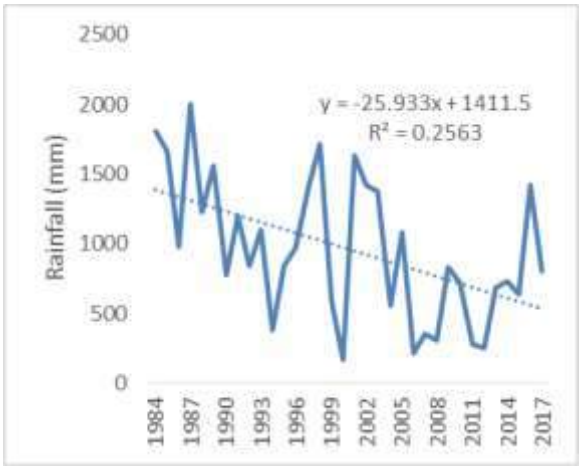
a) April rainfall



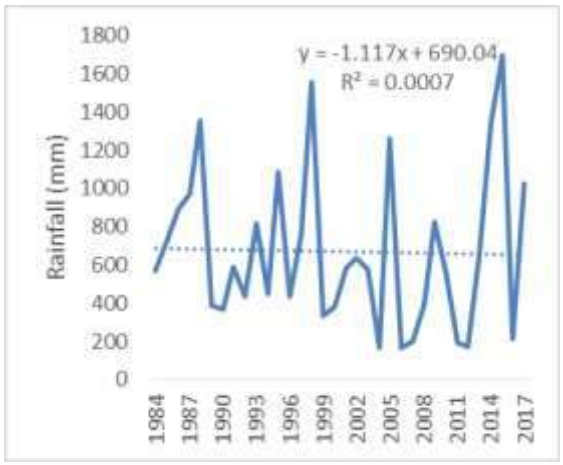
b) May rainfall



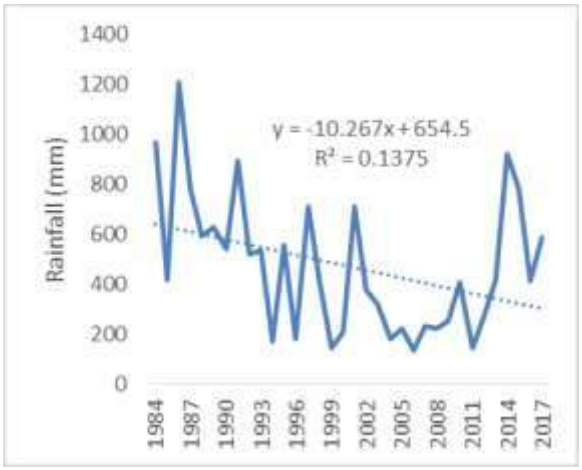
c) June rainfall



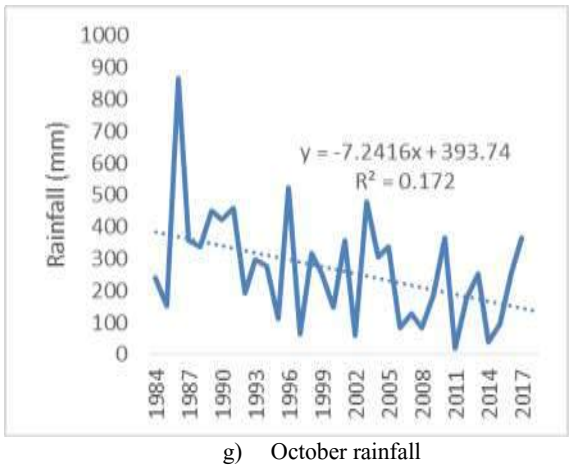
d) July rainfall



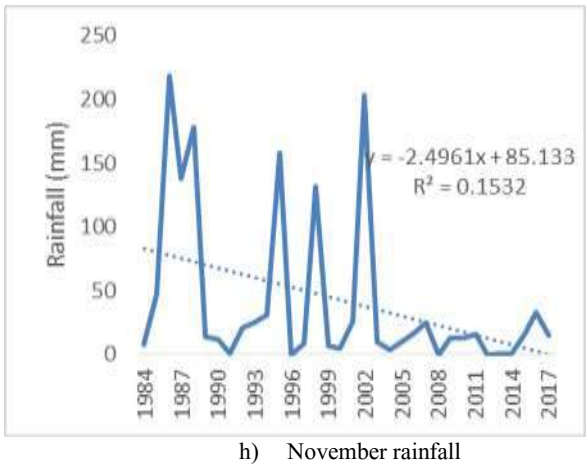
e) August rainfall



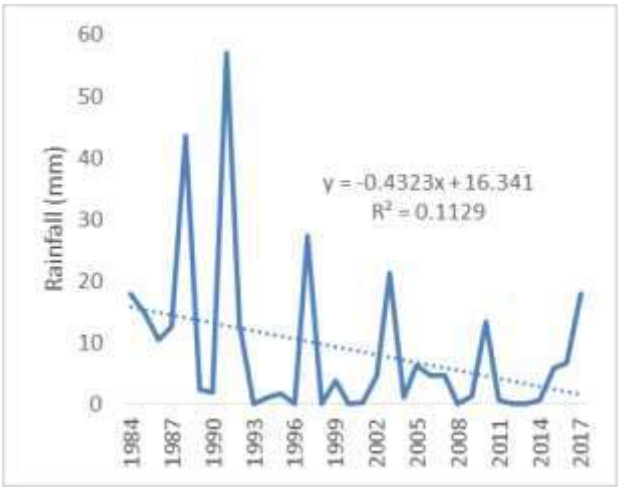
f) September rainfall



g) October rainfall

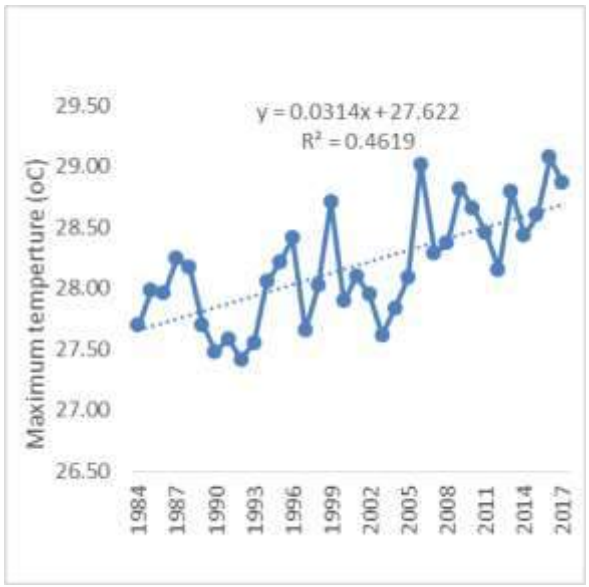


h) November rainfall

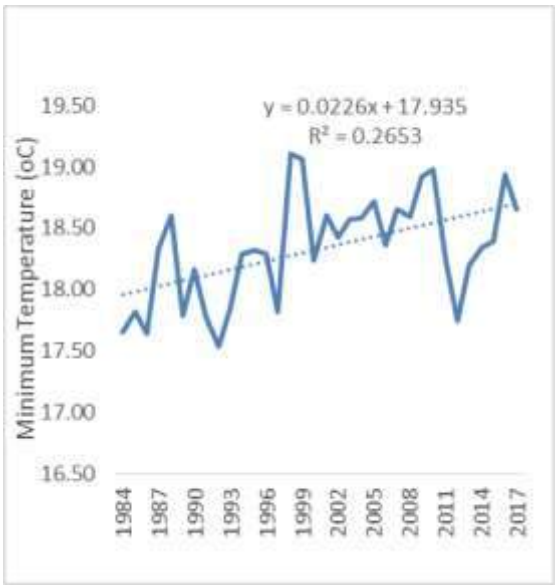


i) December rainfall

Fig 1. Trend in monthly rainfall during 1984-2017 in Meghalaya



a) Maximum temperature



b) Minimum temperature

Fig 2. Trend in minimum and maximum temperature during 1984-2017 in Meghalaya

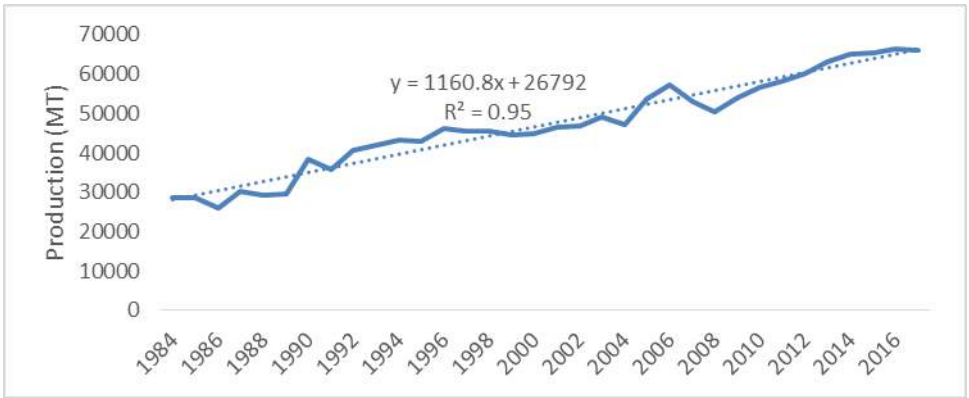


Fig 3. Trend in production of ginger during 1984-2017 in Meghalaya