Effect of Temperature, Rainfall, Cloud, and Humidity on Production of Large Cardamom in Sankhuwasabha, Nepal

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ABSTRACT

The objective of this work was to assess the status of Large cardamom production in the past ten years and impact of meteorological parameters on production of Large cardamom in Sankhuwasabha district, Nepal. Cardamom production data of ten years are taken from statistical information on Nepalese agriculture, Ministry of Agriculture Development. Apart from this monthly data of temperature, rainfall, cloud and humidity are collected from the Department of Hydrology and Meteorology, Khadbari station. The variables under consideration are the cardamom production as a dependent variable and the temperature, cloud, humidity and rainfall as independent variables. P-values and correlation between the dependent and independent variables are calculated using MS EXCEL. Findings of the study shows that Rainfall and Humidity made a significant contribution to the rate of cardamom production forming an upward trend. Temperature gives a downward trend and possesses negative correlation with productivity. Clouds is not significantly related with the cardamom production. The implication of this study for the improvement of cardamom production was discussed.

KEYWORDS: *Large cardamom, production, Sankhuwasabha, Temperature, Humidity and Rain fall*

1. Introduction

Generally, forest plays an important role to enhance quality of environment. In addition, the forest conserves and nurtures biological resources. The forests have undoubtedly been utilized to satisfy the subsistence needs of local people for a long time. Rural communities are totally dependent on forest products i.e. fuel wood, fodder, timber and other non-timber forest products (NTFPs). Nepal hosts a wide range of NTFPs including 700 species of medicinal herbs, which forms an important part of biodiversity and the national economy [1]. In recent years, the market of NTFPs has expanded, and this is an opportunity as well as a challenge for a sustainable, efficient, and equitable management of NTFPs resources [2]. Recent studies indicate that several commercially valuable species are being over-harvested due to higher demand for raw materials for herbal industries in India and other third world countries. Every year, forty –two thousand tons of NTFPs have been harvested in Nepal with a trade value of 26.8 million dollar [3,4]. Rising demand in the market has influenced farmers of Sankhuwasava district to switching from farming traditional crops to cardamom. About 70,000 farmers of eastern Nepal are involved in its production [5].LC basically belongs to the family of 'Zingiberaceae' .It is known as Alaichi in Nepal, BadiAlaichi in Hindi and also renounced as black gold. Because of its black color it is also known as Black Cardamom. The Black cardamom called Queen of species is the most expensive and one of the major cash crops produced in Nepal. Nepal is the largest producer of black cardamom in the world followed by India and Bhutan.Most of the people residing nearby cardamom cultivation area are engaged in its cultivation. Only the smaller portion of the forest is available. Less forest area is available for other purposes and there is no space to extract basic forest products like grasses.

There are sixteen varieties of cardamom in the world. Among them five types of large cardamom are in farming practices across Nepal – Ramsey, Golsey, Sawney, Chibesey and Dammersey [6].The recommended verities of large cardamom (LC) in the cultivation of Nepal are Ramshahi, Golshahi, Saune and Dambarshahi[7]. Cardamom oil is a precious ingredient in food preparations, perfumery, healthy foods, medicines and beverages. Cardamom seeds serve as an astringent, tonic, appetizer and diuretic [8], as a symbol of invitation to neighbors and relatives in marriageor religious functions. Large cardamom is used in Ayurvedic medicine preparation, for example, Dashamularista, Birendramodak and Chawanprash. Besides this it is also used in cake, biscuits, coffee and meat to add flavor [7]. All over the world, the fast-growing food industries depends on spices as taste and flavor makers. In Nepal, the LC is used in meat-deshes andwide range of beverages and sweets. It has been observed that cardamom cultivation is flourishing especially in eastern part of Nepal in height ranging from 700 to 12100 meter from sea level [9]. Large Cardamom is a high-value, low volume crop which uplift socio-economic status of the farmers (FTC, 1998-2007) [10] involved in cultivation. Farmin of Large cardamom have been a major source of getting foreign currency into Nepal [11].Nepal is among the top five highest producer of the cardamom, along with nutmeg and mace, for the last two decades [12]. Nepal is the largest producer of large cardamom covering 55 percent of the average annual world production [13, 14]. Nepal and Bhutan are the major producer as well as exporter accounting about 90 percent of the exported product. Nepal exports 90% of its total production to India. Cardamom cultivation has increased employment opportunities and restricts migration from hill areas to Terai. A study showed that there is shift in the cultivation of the high value crops like cardamom from the traditional cereal crop by the Nepalese farmers between 1995 and 2010 [15]. This diversification created a positive impact on the rural poverty and monthly per capita. Even though large cardamom only covers 10 % volume of the total spices exported, it has the highest share of 86% by value of the spices produced and is the major agricultural export commodity of Nepal [16]. So, large cardamom has been prioritized as agro-based potential export crops and the value chain development programs are also aimed in the production of cardamom [17, 18].

The large contributors of cardamom production in Nepal are Taplejung, Panchthar, Ilam, Sankhuwasabha, and Bhojpur districts[18]. Although there is no consistency in the production and export. Black cardamom is a climate sensitive crops as it thoroughly requires moist soil with filtered sunlight along with the tree plantation around it. The economic yield of LC starts from 3rd year onward after planting and its optimal yield period is 8-10 years. The total life span of the plant is estimated to be around 20-25 years [19]. These districts contribute more than 80% of national cardamom production. Nepalis people prefer plantation of Uttishtrees for the shade required for cardamom plant. Shade helps to regulate soil moisture as well as temperature and provides congenial microclimate for cardamom. We should regulate shade in such a way that cardamom plants receive 50-60% filtered sunlight. Changes in some meteorological factors have a major impact on macro and micro climate which influences the production rate of black cardamom. Deficiency of rainfall and change in temperature are responsible for the increasing and decreasing rate of cardamom production [20]. Air Humidity also play significant role on vegetative and flowering phase of the cardamom.

Table 1: Annual Calendar of large Cardamom and associated hazards

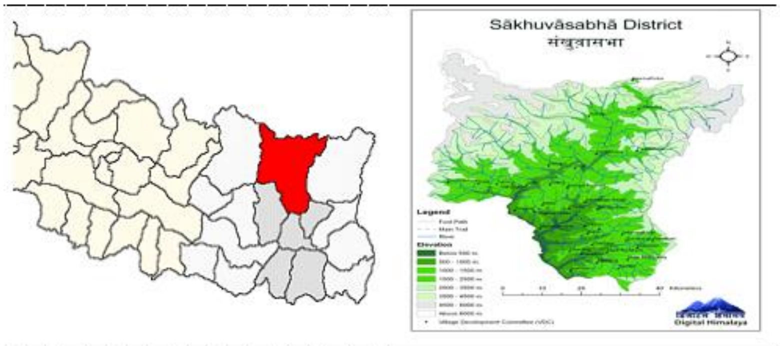
Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop cycle	New spikes germination	Flowering start		Flowering & Fruiting		Maturation/ Ripening			Harvesting			
				First weeding	New plantation				Second Weeding			
Hazards	Drought					Landslide						
	Aphids infection					Water logging						
	Mold/ Clomp Rot (Fungal disease)											
					Leaf Eating Caterpillars							

(Source: Field Study, 2019)

Meteorological Parameters: The variation of meteorological parameters like temperature, cloud, humidity and rainfall play a vital role in the crop growth and its production rate**.** High air temperature reduces the growth of shoots and in turn reduces root growth. Higher level of soil temperature is more crucial results in damage to the roots and reduction in shoot growth. Clouds have potential both for cool and warm climates. At any given moment, about two-third of our planet is covered by clouds. Cardamom plant is a shade loving plant so the clouds are alsoa major factor responsible for their growth. Under proper conditionscloudscome in the form of rain. Water plays a vital role in the overall quality and yield of the cardamom and if it is excess it deteriorates the yield- production. Therefore, an optimum amount of water is required for maximum production of cardamom. The yield is proportional to the water content up to a certain limit, and yield decreases with the excess of water content. In general, humidity is the concentration of water vapor present in the air. Amount of water contained within the soil is the soil moisture. Humidity is important to make photosynthesis possible for the plants. Black Cardamom plant needs a high humid area for its growth.

Fig.1: Life cycle of Black Cardamom plant.

Fig.2: Map of Sankhuwasabha



Study Area: The study was carried out in different VDC of Sankhuwasabhadistrict,Koshi zone, in the eastern part of Nepal. Sankhuwasava district is one among the 16 remote districts of the kingdom of Nepal. It is a mountainous district, situated in the northern part of Koshi zone. The spatial location of this district is between latitude $27^{0}10'$ to 27^{0} 55’N and longitude of $88^{0}57'$ to $89^{0}41'$E. It is surrounded by Taplejung and Terhathum district in the east, Solukhumbu and Bhojpur in the west, Dhankuta in the south and by Tibet of China in the north. On the basis of land area, it is the largest district among the districts of Koshi zone. It has 3,177 sq.km. Area and the size of population are 141903. The density of population is 48.8 per sq.km. (CBS, 2001/2002) and 94.27 percent of the total populations are dependent on agriculture. The famous natural scenarios–Milke, Danda, Kumbhakarna, Lambhasumwa, Pachpokhari, Jaljalae, Sanglungma, PostiBhanjyang have highlighted the position of the district.

Table: 2 General description of Sankhuwasavadistrict

Climate	Sub-tropical monsoon and warm
Soil	Alluvial, Red brown, Lacustrine blackish
Aspect	Valley and Hills
Major rivers	Arun, Sankhuwa ,Sava
Vegetation types	Papal, Kattus, Sallo, Chilaune, Uttis, Okhar, Chap, Rudrakshya, and other NTFPs
Races	Rai, Kami, Tamang, Damai, Sarki, Gurung, Sherpa, Newar, Magar, Limbu, Brahmins

Source :(SuvitaYadav, 2013)

2. Material and Methods.

The objective of our study is to know the effects of meteorological parameters on cardamom cultivation in the Sankhuwashabha. The data used in this paper are from secondary source provided by Ministryof Agriculture and Livestock Development and meteorologicaldata from the Department of Hydrology and Metrology, Khandbari Station for the period of 2010 – 2019(10 years).The formula used to calculate Pearson correlation coefficient is given by

$$r = n(\sum xy) - (\sum x)(\sum y) / \sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}$$

Where r is Pearson correlation coefficient, x, y are values of the first and second set of data.

3. Results and Discussion

The large cardamom is one of the oldest indigenious spices of the eastern Himalay whose production area and total production were slightly fluctuating in different years. Farmers cultivated around 2770 hect and produced about 400 Kg/ha. Data of production rate in different years has been shown in Table1 below.

Table 3: Production rate of long cardamom in Shankhuwashabha district.

Year	Productive Area (ha).	Total Production(ton)	Production (Kg/ha)
2010	2710	949	350
2011	2710	949	350
2012	2725	1036	380
2013	2635	940	360

2014	2730	955	350
2015	2770	1108	400
2016	1900	1108	580
2017	2200	1129	510
2018	1985	1058	530
2019	2150	1140	530

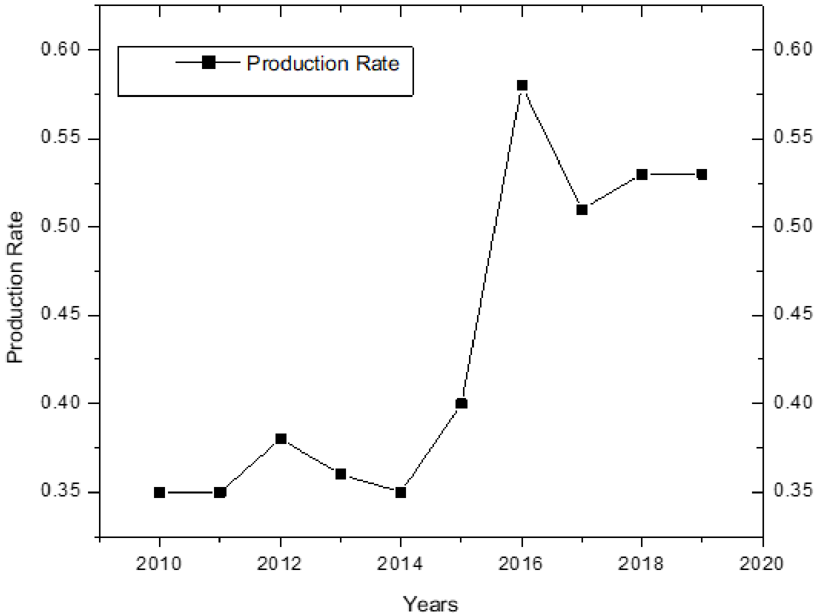


Fig.3: Production trend of LC in the period 2010 to 2020

It is seen that the productivity started from 2015 to 2016 and then decreased.

Table 4: The data of Average Temperature, Average Rainfall, Average Humidity and Average Cloud along with production rate has been shown below in Table.

Year	Avg. Annual Temp. ^{0}C	Avg. Annual Rainfall(mm)	Avg. Annual Humidity (%)	Avg. Annual Cloud (%)	Productivity (Kg/ha)
2010	15.5	198.179	64	43.13	350
2011	15.66667	148.26	62.416	43.02	350
2012	16.25	92.24	52.916	38.78	380
2013	16.88181	112.41	56	33.87	360
2014	16.0833	123.64	56.58	30.73	350
2015	12	370.18	65.5	31.45	400
2016	12.666	377.21	65.916	33.51	580
2017	12.0833	408.99	65	35.95	510
2018	11.5	308.2275	68.666	30.30	530
2019	12.5	236.78	71	36.30	530

Large cardamom, also known as black cardamom, is one of the oldest indigenous spices of the eastern Himalayas whose production area and total production were slightly fluctuating according to year. The farmers cultivated around 2770 ha and produced 1108 ton with 400 Kg/ha in 2015 which declined to 1900ha but produced 1108 tons with 580Kg/ha in 2016. In the year 2010, the production area was around 2710ha and produced 949 tons with 350Kg/ha while in the year 2019, the farmers cultivated around 2150ha but produced 1140 ton with 530 Kg/ha.

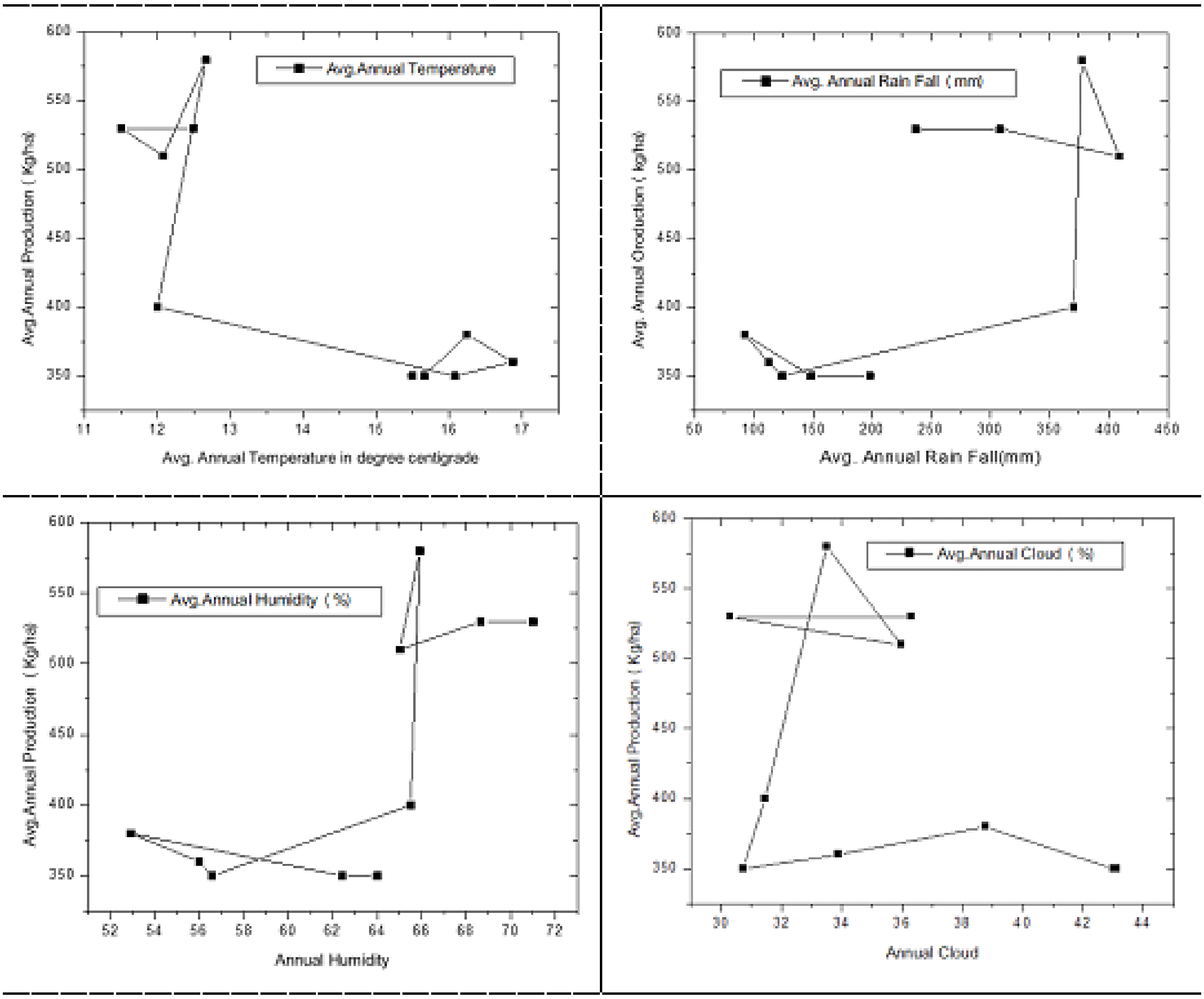


Fig.4: Variation in Productivity of Large Cardamom with meteorological parameters (a) Temperature (b) Rainfall, (c) Humidity and (d) Cloud

In above four curves are for the effect of metrological parameters on the productivity of large cardamom.The 1st curve from the top gives variation of Productivity against Temperature. The line graph illustrates that lower the temperature higher would be the productivity and vice-versa. The second curve from the top is for the effect of Rain Fall on the Productivity. From the line graph we observed that the average annual rainfall ranging from 100mm to 200 mm has the lowest production rate (upto 375kg/ha) whereas for rainfall above 200m has the highest production rate ranging from 400kg/ha to 550kg/ha. First graph shows the variation in productivity due to change of Humidity in air. The line graph shows that the humidity ranging from 53% to 64% has the lowest average annual production whereas the humidity above 65% has the better production rate.It has been concluded that cloud does not have any apparent effect on the large cardamom production.

Table 5: Average Monthly Temperature Data

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2010	9	10	15	18	17	18	18	20	19	18	14	10
2011	8	10	15	16	19	21	21	20	20	17	12	10
2012	7	10	14	17	20	22	22	21	21	17	13	11
2013	8	11	16	18	20	21	21	20	20	17	13	10
2014	9	10	14	19	20	22	22	20	19	17	13	9
2015	7	7	10	12	15	16	16	16	16	13	10	6
2016	4	8	12	15	15	16	16	17	15	13	11	9
2017	6	8	8	13	15	16	16	16	16	13	9	9
2018	5	8	10	12	13	16	16	16	16	11	9	5
2019	5	6	9	13	15	17	17	18	16	13	12	6
Grand Total	**68**	**88**	**123**	**153**	**169**	**185**	**185**	**184**	**178**	**149**	**116**	**85**

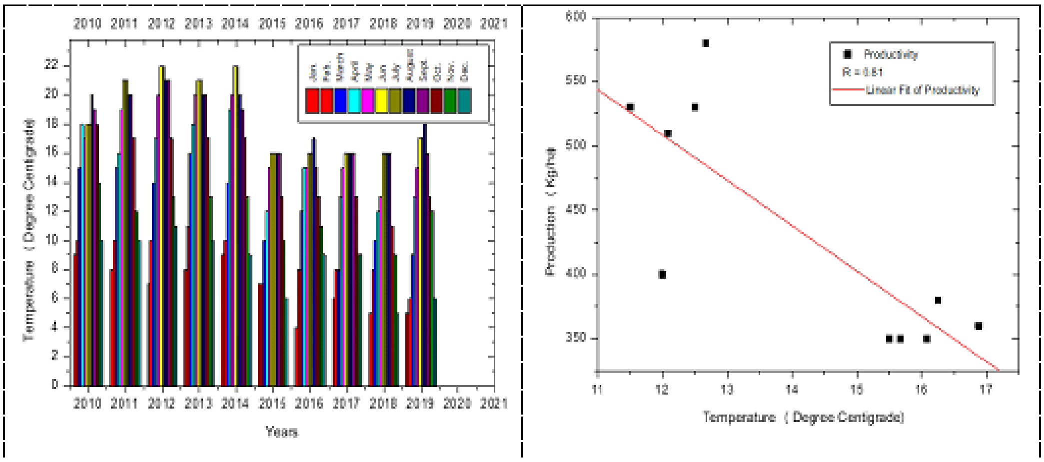


Fig. 5(a) Bar diagram showing monthly variation of Temperature in different years and Fig.5(b) Linear Fit of productivity with the Annual Average Temperature.

The Probability value (P-value) or calculated probability value is a number describing how likely it is that your data would have occurred by random chance (i.e. that the null hypothesis is true). The level of statistical significance is often expressed as a P- value between 0 and 1. Smaller is the p-value, stronger the evidence that you should reject the null hypothesis.

- P- Value less than 0.05 is statistically significant. It indicates strong evidence against the null hypothesis, as there is less than 5% probability the null is correct (and the results are random). Therefore, we reject the null hypothesis, and accept the alternative hypothesis. However, if the p-value is below your threshold of significance (typically P< 0.05), it can be rejected the null hypothesis, but this doesn't mean that there is a 95% probability that the alternative hypothesis is true.
- P- Value higher than 0.05 is not statistically significant and indicates strong evidence for the null hypothesis. This allows us to reject the alternative hypothesis and there is no significant relationship between dependent and independent variables. In the case of alternative hypotheses, there is a significant relationship between dependent and independent variables.

From the above table, P-value=0.004 which is lesser than 0.05 which shows that there is a significant relationship between temperature and productivity. There was a negative correlation between temperature and productivity having regression coefficient of (r) =0.81523. The average annual temperature and production shows a downward trend showing the increase in temperature decreases the production and vice-versa. Further, observing the average annual temperature of ten years we found that the average annual temperature of the first five years (2010 - 2014) is 16.0636^{0}C, which is greater than the five years period (2015 – 2019) whose average annual temperature is 12.15^{0}C.

Average annual temperature data: From the bar diagram it can be seen that the first five years from 2010 to 2014 had more average annual rainfall than the last five years. Among the ten year data, 2013 had the highest average annual temperature that is 16.81 degree centigrade and 2018 had the least average annual temperature that is 11.5 degree centigrade.

Table 6: Average monthly rainfall data

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2010	0.3	35.85	59.2	191.5	253.4	373.5	706.2	476.9	476.9	476.9	36.84	9.7
2011	15.52	14.18	59.3	120.2	198.4	218.4	388.8	417.01	417.01	417.01	22.6	3
2012	5	33.6	28.7	96.6	142.7	177.4	270.4	213.01	213.01	213.01	1	0.1
2013	3.8	35.3	9.5	41.3	161.5	151.7	276.6	320.4	320.4	320.4	1.5	7.3
2014	3.7	5.9	13.62	35.9	161.9	253.3	355.1	402.63	402.63	402.63	8.32	0.78
2015	8.1	36.5	152.4	244.3	359.6	818.1	1285	888.73	888.73	888.73	16	17.5
2016	53.74	22.8	51.3	113.8	331.1	676.5	1281	851.36	851.36	851.36	22.39	16
2017	12.02	5.49	253.8	351.5	534.2	767.1	1475	891.4	891.4	891.4	18.2	1.8
2018	10.3	45	104.6	264.6	462.6	490.2	946.2	1035.5	1035.5	1035.5	12.4	29.2
2019	18.5	75.4	75	322.9	419.1	391	612.3	367.7	367.7	367.7	41.2	47.9
Grand Total	**130.98**	**310.02**	**807.4**	**1783**	**3024**	**4317**	**7597**	**5864.6**	**3350.44**	**1014.6**	**180.45**	**133.28**

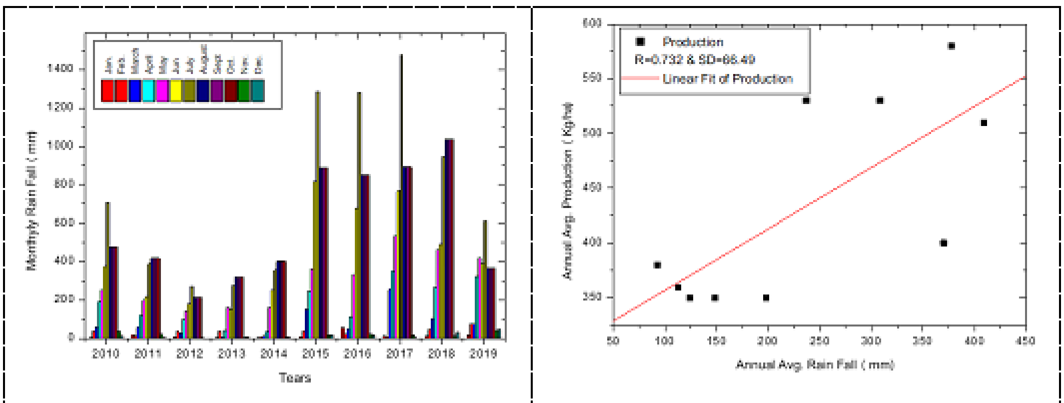


Fig. 6 (a) Bar diagram showing monthly variation of RainFall in different years and **Fig.6 (b)** Linear Fit of productivity with the Average Rain fall.

From the above table, P-value = 0.0160581 which is less than 0.05 which shows that there is a significant relationship between rainfall and productivity. There is a positive correlation between average annual rainfall and productivity with r=0.732148. The average annual rainfall and production (Kg/ha) shows an upward trend which indicates that the increase in rainfall increases the production. From the above bar-diagram we found that the average annual rainfall of first five years

(2010 - 2014) is 134.944mm, which is less than the next five years (2015- 2019) that is 340.26 mm.

Average annual rainfall data: The bar diagram illustrates that the first five years consists of less average annual rainfall in comparison to the last five years. From the first five year 2012 had the least average annual rainfall that is 92.24 mm and 2017 had the highest average annual rainfall of 408.9925 mm.

Table 7: Average monthly humidity data

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2010	36	41	46	49	72	83	83	80	76	64	76	53
2011	56	45	39	47	65	69	69	79	75	67	72	55
2012	40	34	41	45	54	70	70	76	72	47	41	38
2013	33	30	35	42	59	70	70	77	72	68	55	54
2014	39	38	34	32	53	71	71	80	76	63	70	46
2015	35	48	48	56	67	79	79	89	83	70	68	55
2016	63	44	36	43	67	83	83	84	86	76	64	56
2017	30	44	54	59	69	80	80	91	85	73	57	49
2018	53	54	48	66	78	82	82	90	83	64	64	52
2019	40	48	47	67	68	83	83	89	91	81	78	68
Grand Total	**425**	**426**	**428**	**506**	**652**	**770**	**851**	**835**	**799**	**673**	**645**	**526**

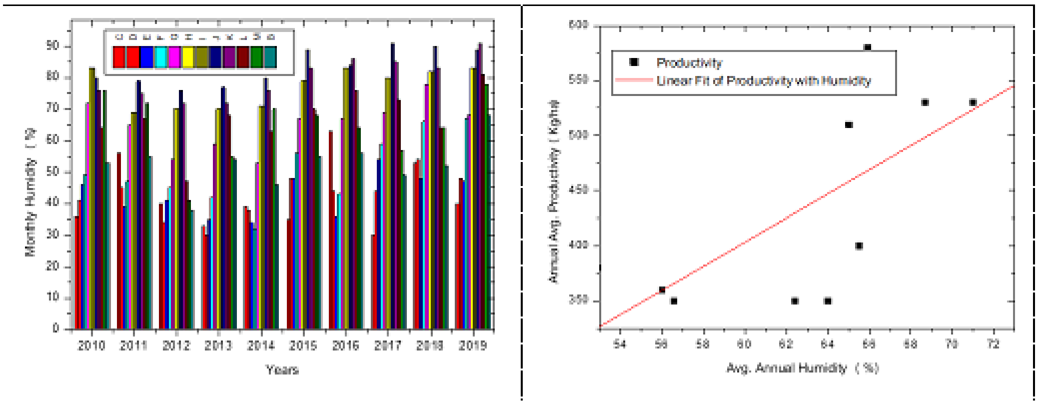


Fig. 7(a) Bar diagram showing monthly variation of humidity in different years and **Fig.7(b)** Linear Fit of productivity with the annual average humidity.

From the above table, P-value =0.025353297 which is lesser than 0.05 which shows that there is a significant relationship between humidity and productivity. There is a positive correlation between average annual humidity and productivity having r= 0.69611. The average annual humidity and production (Kg/ha) shows an upward trend indicating increase of humidity increases the production. We came to know that the first five years (2010 - 2014) the average annual humidity data is 58% which is far less than the next five years (2015- 2019) having 66%.Average annual humidity data: The bar diagram illustrates that there is no such fluctuation regarding average annual humidity in these ten years. 2012 had the least average annual humidity that is 52.91% whereas 2019 had the highest average annual humidity that is 71%

Table 8: Average monthly cloud data

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
2010	2	5	7	10	24	36	64	33	25	12	17	6
2011	10	7	13	9	14	22	34	31	24	11	11	6
2012	5	5	6	7	10	20	28	26	19	3	2	1
2013	3	7	4	8	15	23	29	27	18	16	5	7
2014	4	7	8	5	12	19	30	33	22	9	11	5
2015	6	10	23	23	23	44	77	78	59	25	15	14
2016	18	7	9	23	30	60	80	63	64	35	15	10
2017	5	7	24	21	23	49	73	65	42	23	9	5
2018	7	14	9	19	32	39	61	62	37	14	10	9
2019	12	18	9	21	18	33	62	45	56	26	27	16
Grand Total	**72**	**87**	**112**	**146**	**201**	**345**	**538**	**463**	**366**	**174**	**122**	**79**

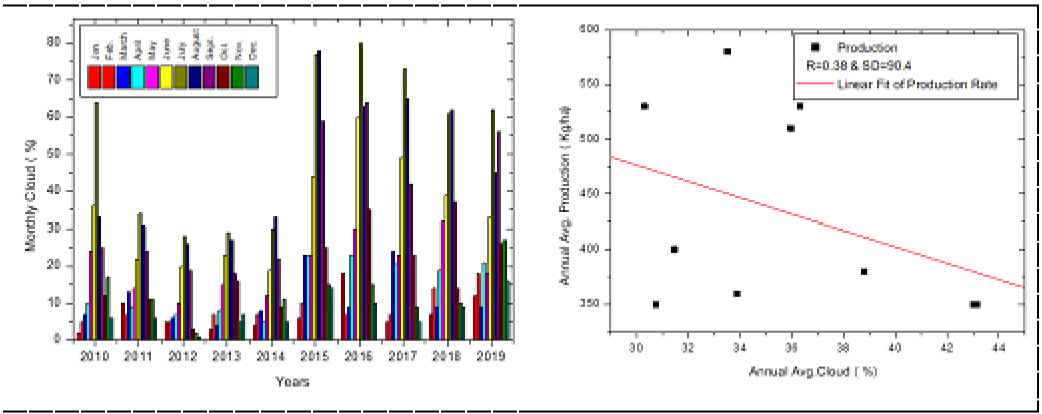


Fig. 8(a) Bar diagram showing monthly variation of Cloud in different years and**Fig.8(b)** Linear Fit of productivity with the Annual average Cloud.

From the above table, P-value =0.4842481 which is more than 0.05 which shows there is no significant relationship between cloud and productivity. There was a negative correlation between average annual cloud and productivity having r= 0.25099606. The average annual cloud and production (Kg/ha) shows a downward trend which indicates an increase in cloud decreases the production and vice-versa. Average annual cloud data: It can be seen that clouds of every year are almost similar and range from 30% to 43%.

Conclusion

The study showed that there exist direct and indirect influence of some meteorological factors like temperature, rainfall and humidity in production of large cardamom in Sankhuwasabha. There is a strong negative correlation between productivity and temperature. The downward trend shows that higher the temperature, the lower will be the productivity. There is a significant effect of rainfall on productivity. Positive correlation indicates that higher the rainfall higher will be the productivity. The significant correlation between humidity and productivity shows that humidity enhances the productivity of large cardamom but presence of cloud percentage in sky has negative correlation with productivity.

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