Assessment of the perceptions of tea farmers on the effect of temperature and rainfall variation on tea production in Kisii County, Kenya

Research article

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Abstract

The study aimed to assess the perceptions of tea farmers on the effect of temperature and rainfall variation on tea production in Kisii County. It adopted a correlational research design. The sample size was 400 farmers but only 352 farmers returned duly signed questionnaires. The study targeted small scale tea farmers, Kisii Meteorological Department, and three Kenya Tea Development Agency factories of Kisii County. The study used mixed methods to collect primary data from small scale tea farmers and document analysis was used to collect secondary data. The findings of the study revealed that the perception of the farmers concerning the effects of temperature is that scanty rainfall reduces tea yields, heavy rainfall causes erosion of top soil and washes away available fertilizer thus affecting tea production, and that frostbites reduce tea yields and production significantly since hailstones destroy the tea leaves and reduces tea yields drastically.

Keywords: crop production, perceptions, rainfall pattern, rain-fed, temperature variation, tea leaves

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Public Interest Statement

Results from this study will help farmers to identify sustainable adaptation strategies and diversify their farming activities, policy makers like the ministry of Agriculture and county government to adopt policies which will enhance sustained production.

Introduction

According to the World Meteorological Organization (WMO), the physical signs and socio-economic impacts of climate variability and change are accelerating as increase in greenhouse gas concentrations drive global temperatures towards increasing dangerous levels (WMO, 2018). The IPCC fifth report (AR5) has indicated that the past three decades have been warmest in the history of instrumental records, with each decade being warmer than the preceding period (IPCC, 2014). Observational records have also shown that during the 20th century the temperatures in the African continent rose by about 0.05°C per decade with slightly larger warming in the season from June to November as compared from December to May (Hulme et al., 1998; IPCC, 2001). Such extreme temperatures affect the rate of plant development which in turn affect crop yields (Hatfield & Prueger, 2015).

By 2000, the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is similar to that experienced globally, and the periods of most rapid warming in the 1910s to 1930s and the post 1970s occur simultaneously in Africa and the rest of the world (IPCC, 2001). The WMO report and NASA have also indicated that the years that is 2015, 2016 2017 and 2018 were warmest in record with the global average temperatures in 2018 being higher in nearly 140 years of records kept (WMO, 2019). These changes in temperatures have affected precipitation patterns which in turn has affected crop productivity. It has also been noted that the patterns of the average and maximum temperatures in tea producing regions have undergone marked changes in the recent past (Dutta, 2014). Further, extreme weather events, such as drought, heavy, torrential rains and frosts, have become more frequent, and these phenomena have had negative effects on agricultural systems in general and on tea production in particular (Bett, 2016; FAO, 2016; Gunathilaka, Smart & Fleming, 2017).

These climate variations have affected rain-fed agriculture which supports a large portion of the Kenyan population. About 75% of Kenya's population depends on agricultural foods and income from cash crops that contributes 26% to the Gross Domestic Product and 60% to foreign exchange earnings (Perret, 2006). These climate variations have potentially affected agricultural production which essentially affects the rural economy, food security, and balance of trade leading to reduced foreign exchange earnings (Kariuki, 2016). A study done by Thornton, (2011) found out that climate change has negatively affected crop production in Kenya due to predominance of rain-fed agriculture, low adaptive capacity, and inadequate capital to adapt to these changes.

In Kisii County, smallholders play an important role in tea sub-sector and other parts of the world. Notably, in Sri Lanka there are more than 400,000 smallholders accounting for 76% of its total tea production and 64% of the total area under tea (Agritrade, 2011). In Indonesia, they account for 43% of the area under tea and 23% of its production. In Kenya, an estimated 560,000 smallholders account for 62% of total tea production. But research has shown that climate variability already has had substantial impacts on biological systems, on the smallholder farms, communities and countries that depend on rain fed agriculture (Thornton et al., 2014). Further, it has been noted that climate variability and change has endangered the lives of smaller holder farmers because most of them rely on rain-fed agriculture and financial support that can help them invest in more climate resilient agriculture (Holland, 2017; Morton, 2007). During the recent years, the tea industry has been faced with challenges such as; low yields from smallholder farmers, high cost of production and impacts caused by climate change and variability (Nyaga, 2017).

Literature Review

Perception of Farmers on Climate Variability

Different population groups have different perceptions on climate variability (Haque et al., 2012). Some perceive it in terms of rainfall and temperature variations, others perceive it from extreme climatic events such as floods and droughts and others from crop failure, reduced crop yields and reduced water resources. Many farmers worldwide have been experiencing climatic changes as reported through rising temperatures, unpredictable and reduced rainfall which has led to reduced yields (Karki, 2019). It has been noted that assessing different levels of farmers' perception is paramount for successful efforts to curb negative effects of climate variability and change on Agriculture. Further, perception of the severity of climate variability and change in agriculture and water resources is an important prerequisite in coping and adapting to these changes since they influence the farmer's responses (Patt &Schroter 2008; Ochenje, et al., 2016). Adaptation at the farm level will not take place unless farmers perceive variations in the climatic elements.

Most researchers such as Roncili, et al., (2002); Vogel & O' Brien, (2006) and Thomas, et al., (2007), have argued that environmental perceptions are among the key elements which influence the adoption of adaption strategies, planning and management of agricultural activities taken by farmers. Maddison (2006) described that adaptation to climate change requires the perception of farmers that there has been a spatial variation of climate over time and then choose useful adaptations and implement them. Sledgers

(2008) as cited by Moyo et al., (2012) has also indicated that an important factor that shapes a farmer's perception is experience. In terms of seasonality, bad experiences of the seasons, when extreme climatic conditions such as droughts affected agricultural production, can be remembered. In agreement to the above, a review done on the experiences and perceptions of farmers about climate change and variability on research articles up to 2016, revealed that farmers worldwide have been experiencing climate changes mainly regarding rising temperature, unreliable and reduced rainfall which have ledto the reduction of the agricultural produce (Karki, Burton & Mackey, 2020; Hitayezu, Wale & Ortmann 2017).

Research done in Songkhla Lake Basin in Thailand on farmers' perception of the effect of climate variability on crop production revealed that change in temperature and rainfall had led to reduction of crop production and these affected farmers involved in fruit production, and fisheries adversely (Somboonsuke et al., 2018). This is in agreement with a study conducted on perceptions of farmers on climate change and variability in Central America which revealed that smallholder farmers perceived that climate has been changing with most of them reporting the rise in temperatures, low annual rainfall and seasonality of the rain season (Harvey et al., 2018). Also, a study done in North West Ethiopia, on the perception of farmers to climate variability showed that the number of crop failures in the past, changes in temperature and precipitation significantly influenced farmers' perception on climate variation in wet lowland parts of the study area. In dry lowland conditions, farming experience, climate information, duration of food shortage, and the number of crop failures experienced determined farmers' perception of climate change (Paulos & Belay, 2018).

A study that was done using participatory research techniques in two semi-arid regions of Zimbabwe on farmers perception on climate variability and the correspondence of these perceptions with historical climate data revealed that farmers perceived that there were variations in climatic and weather patterns over the past decade and also indicated that there were erratic rainfall patterns, decreased rainfall and temperature increases, which led to a decline in crop production and increased livestock morbidity and mortality (Mvumi et al., 2012). This agrees with a study of South African farmers' adaptation to climate variability and change (Bryan et al., 2009), where it was observed that 95 percent of the farmers perceived that temperature had changed over time while 97 percent of them thought there has also been a change in rainfall. Extreme weather events had been projected to increase in the Southern Africa region which is frequently affected by frequent drought occurrence due to its characteristic low rainfall index and variability (Rakgase & Norris, 2015; Stringer et al., 2009). In contrast to the above, a study conducted in a semi-arid

Basin by Shimola and Krishnaveni, (2017) on farmers perception on climate variability revealed that the majority of the farmers reported that rainfall had been decreasing and they had experienced high incidences of droughts that forced them to opt for other sources of income.

A comparison of farmers' perception of climate variability with climatological data was made in South Africa. The response of the farmers was consistent with that of the climatological data which revealed that there was a decrease in the total annual rainfall from 2006-2015 (Rapholo, 2020). This study is in agreement with the one conducted in the semi-arid highlands of Northern Ethiopia where 92 percent of the farmers perceived that annual rainfall had decreased from 1983 to 2015 (Kahsay, Guta & Gidey, 2020). In South Africa, a study was conducted in the rural Limpopo Province on the perception of smallholder farmers on climate variability and crop production and household livelihood by Ubisi, et al., (2017). The study found out that 56.4 percent of the smallholder farmers perceived prolonged droughts as the main factor affecting crop productivity. This is in agreement with a study done in the Central River Region of Gambia where most farmers perceived an increase in the occurrence of extreme events. Almost all farmers that is 90 percent considered drought as the main factor affecting agricultural activities in the area (Begagnan, Ouedraogo & Fonta, 2019).

A review was done by Sani and Chalchisa (2016) on farmers' perceptions on impact and adaptation strategies to climate change among small-scale farmers in Sub- Saharan Africa. It was revealed that most farmers were aware of climate change and variability which was manifested in changes in precipitation patterns. This agrees with a study conducted in five Counties of Eastern Province in Kenya on farmers' perception on rainfall variability and its associated risks. Farmers were aware of the rainfall variability and its effects on crop production but were not able to recognize the long-term trends (Rao, et al., 2011). In Kisii Sub County, a study done on the perception on the effects of rainfall variability on crop production and household security, results showed that farmers perceived that it led to reduced yields, reduced water availability and increased crop and animal diseases (Otiso, 2016).

Research Designs and Methods

The study used interview schedules and questionnaires to collect primary data from field service coordinators and small-scale tea farmers respectively. Document analysis for secondary data was used to collect monthly rainfall and temperature data from 1995 to 2019 from the KALRO's Kisii Meteorological Department and tea yields from KTDA factories for the years 1996 to 2019. Two research assistants were used to administer questionnaires to the farmers and interviews were administered to the field service coordinators by the researcher.

The study targeted six Kenya Tea Development Agency (KTDA) factories and six field service coordinator personnel from the six factories, 120,000 small scale tea farmers (KTDA, 2017) who supply their tea to the six factories, and personnel from the meteorological department of Kisii County to provide information on monthly tea production totals from 1996 to 2019 and monthly rainfall and temperatures from 1995 to 2019 respectively. This study adopted a correlational research design. As it is used to examine a relationship between two concepts (Walliman, 2011). Correlational research design explores the relationship between variables and measures the intensity of the relationship. Whenever variables change in the same direction, the relationship is said to be positive while a negative relationship occurs when one variable increase while the other is decreasing. No relationship occurs when there is no identifiable pattern (Thompson et al., 2005; Slavin, 1992). This design was important for this study because it was used to examine the relationship between rainfall and temperature variations and tea production. Both quantitative and qualitative approaches were used in collecting and analyzing data. The factories that were chosen included: Kiamokama, Nyamache and Ogembo. Data on monthly tea production from 1995 to 2018 was collected from field service coordinators of the three sampled tea factories. The study used a sample size of 400 farmers as calculated by Yamane, (1967) at 95 % confidence level.

Results and Discussion

Perceptions of Tea Farmers on the Effect of Temperature and Rainfall Variation on Tea Production

The study sought to assess the perceptions of tea farmers on the effect of temperature and rainfall variation on tea production in Kisii County. To respond to this objective, the respondents were required to give their level of agreement with statement regarding the effects of rainfall and temperature variability on tea production.

Effect of Rainfall Variability on Tea Production

Respondent's perceptions about rainfall variations were assessed by gauging their level of agreement on various statements. These statements used likert scale of 1-4 where 1 was strongly agree while 4 was strongly disagree. The results for the statements regarding effects of rainfall variability on tea production were as follows.

Table 1: Effect of Rainfall Variability on Tea Production

		Strongly agree	Agree	Disagree	Strongly disagree	Mean	Std. Deviatio
Scanty rainfall reduces tea yields	N	269	65	14	4	1.30	0.598
	%	76.4	18.5	4.0	1.1		
Heavy rainfall causes erosion of top soil and washes away available fertilizer	N	116	216	1	19	1.78	0.708
	%	33.0	61.4	0.3	5.4		
Frostbites reduces tea yields and production significantly	N	73	268	9	2	1.83	0.477
	%	20.7	76.1	2.6	0.6		
Hailstones destroy the tea leaves and reduces tea yields drastically	N	102	218	14	18	1.85	0.717
	%	29.0	61.9	4.0	5.1		
Heavy rainfall destroys tea clones	N	47	113	188	4	2.42	0.732
	%	13.4	32.1	53.4	1.1		
Rainfall changes affects soil water availability to tea clones	N	66	84	177	25	2.46	0.876
	%	18.8	23.9	50.3	7.1		
Rainfall changes affects farmer's decision on when to apply fertilizers	N	55	109	134	54	2.53	0.933
	%	15.6	31.0	38.1	15.3		
Rainfall variability leads to emergence of pest which were never experienced before	N	79	30	75	168	2.94	1.209
	%	22.4	8.5	21.3	47.7		

Source: Field data, 2020

Based on results presented in Table 1, most of the respondents (94.9%) generally agreed (reporting both agree and strongly agree) that scanty rainfall reduces tea yields. Moreover, 94.4% of the respondents were in agreement that heavy rainfall causes erosion of top soil and washes away available fertilizer thus affecting tea production. Further, 96.8% of the respondents concurred that frostbites reduce tea yields and production significantly with 90.9% ascertaining that hailstones destroy the tea leaves and reduces tea yields drastically. Informed by the mean scores, the rainfall aspects that greatly affected tea production were Scanty rainfall (M=1.30), effect of heavy rainfall on erosion of top soil (M=1.78), effects of frostbites (M=1.83) as well as the effects of hailstones (M=1.85). On the effect of rainfall variability on tea, one of the field service coordinators reported as follows:

> *Tea yields have been fluctuating as a result of variation in rainfall. Indeed, during the season of heavy rainfall, tea yields reduce as a result of lack of sunshine. Low rainfall on the other had is detrimental as the is no enough water to enhance shoot growth. This reduces the cycle of tea picking among tea farmers*

Another field service coordinator reported the following:

> *Hailstones experienced in the tea growing areas have become a serious menace to the farmers over decades. Once this occurs, the tea plant is affected and this reduces yields drastically as it takes a longer period of time for the plant to regain. Indeed, we lack a solution for this. Further, as noted from farms where tea is grown on low lands waterlogging has also affected tea production leading to stunted growth hence reduced yields*

The results revealed that scanty rainfall reduces tea yields (94.9%). The results are in consistent with Karki, Burton & Mackey, (2020); Hitayezu, Wale & Ortmann (2017) who revealed that farmers worldwide have been experiencing changes in climate mainly regarding rising temperature, unreliable and reduced rainfall which have led reduction of the agricultural produce.

Furthermore, a research done by Somboonsuke et al., (2018) in Songkhla Lake Basin in Thailand on farmers' perception on the effect of climate variability on crop production revealed that change in temperature and rainfall had led to reduction of crop production and these affected farmers involved in fruit production, and fisheries adversely. This was in agreement with an investigation made by Harvey et al. (2018) on farmer's perceptions to climate change and variability in Central America which revealed that, smallholder farmers perceived that climate has been changing with most of them reporting rise in temperatures, low annual rainfall and seasonality of the rain season.

Moreover, heavy rainfall causes erosion of top soil and washes away available fertilizer thus affecting tea production (94.4%.) Further, results showed that frostbites reduce tea yields (96.8%) and production significantly with 90.9% ascertaining that hailstones destroy the tea leaves and reduces tea yields drastically. The results support those of Otiso (2016) who carried a study in Kisii Sub County, on the perception on the effect rainfall variability on crop production and household security, the results showed that farmers perceived that it led to reduced yields, reduced water availability and increased crop and animal diseases.

Indications of Rainfall Variations

Rainfall variations were indicated by various factors. These were the aspects that the respondents experienced to ascertain that indeed variations in rainfall had an effect on tea production. Further, the respondents were sked to give their level of agreement with statements regarding the various indications of rainfall variations. The findings were as shown in table 2 below.

Table 2: Indications of Rainfall Variation

		Strongly agree	Agree	Disagree	Strongly :	Mean	Std. Deviation
Change of planting date to onset of Rainfall	n	268	56	26	2	1.32	0.634
	%	76.1	15.9	7.4	0.6		
Change of planting and harvesting Seasons	n	230	88	32	2	1.45	0.682
	%	65.3	25.0	9.1	0.6		
Unpredictable rainfall amounts	n	93	249	10	0	1.76	0.488
	%	26.4	70.7	2.8	0.0		
Crop failure due to drought	n	38	300	14		1.93	0.379
	%	10.8	85.2	4.0			
Short rainy season	n	57	258	37	0	1.94	0.514
	%	16.2	73.3	10.5	0.0		
Rainfall delays	n	112	50	182	8	2.24	0.932
	%	31.8	14.2	51.7	2.3		
Early onset of rainy season	n	64	89	197	2	2.39	0.784
	%	18.2	25.3	56.0	0.6		
Early exit of rainy season	n	54	91	42	165	2.90	1.156
	%	15.3	25.9	11.9	46.9		

Source: Field data, 2020

As evidenced in the table above, majority of the respondents (97.2%) were in agreement that rainfall variation was indicated by the unpredictable rainfall amounts as well as the change of planting date to onset of rainfall (92%). This was followed by Change of planting and harvesting seasons as reported by 90.3% of the respondents, crop failure due to drought (96%), short rainy seasons (89.5%), rainfall delays (46%), early onset of rainy season (43.5%) and early exit of rainy season (41.2%).

From the above results and based on the mean scores, change of planting date to onset of rainfall (1.32), change of planting and harvesting seasons (1.45), and unpredictable rainfall amounts (1.76) were the main indicators of rainfall variations in Kisii County.

The above results are in agreement with Amadou et al., (2015) who found that about 99% and 98% of interviewed farmers reported that there is a long-term change in the start and end of the rainy season. In terms of the date of the onset of rainy season, 97% of respondents reported that the late dates of onset which have been shifting from April to June during the last 20 years while only 2% of them reported that the dates of the onset are early. Further, 96% of the farmers reported that the dates of the end of the rainy season are early and have shifted from November to October over the last 20 years. The findings are also in agreement with Maddison, (2006) and Thornton et al., (2006) who found out that temperatures are continuously increasing while rain has become more variable and duration shortened. Further, Mugalavai et al., (2008) noted that there was high variability on the onset and cessation of the rainy season. But the results contrast with climatological data which showed that the rainy seasons in Ghana end late (Amadou et al., 2015). During the interview one of the field service coordinator reported the following:

> *Indeed, there has been variations in the amount of rainfall and temperature received in the tea growing areas over the past decades. The onset and intensity of rains has been varying overtime. Also, the night temperature has increased as evidenced by the great heat experienced during the night.*

The above statement supports Resilience Policy Team-Irish Aid (2015), who found that the number of hot days and nights had increased independent of the season. Between 1960 and 2003 the average annual hot days and nights had grown from 30 to 41 in Sri Lanka.

Effect of Temperature Variability on Tea Production

Similarly, the study also sought to determine the effect of temperature variability on tea production and the results are as shown in table 3 below.

Table 3: Effect of Temperature Variability on Tea Production

		Strongl	Agree	Disagr	Strongl	Mean	Std.
High temperatures cause high transpiration rates leads to reduced yields	N	2 5	9 3	0	0	1. 2	0. 4

		9				6	42
	%	73.6	26.4	0.0	0.0		
High temperatures cause high evaporation from the soil leading to stunted growth, hence reduced yields	N	115	230	7	0	1.69	0.503
	%	32.7	65.3	2.0	0.0		
High temperatures lead to wilting and drying of tea	N	30	286	4	32	2.11	0.671
	%	8.5	81.3	1.1	9.1		
Cold conditions damages tea leaves and roots leading to low productivity	n	32	99	220	1	2.54	0.661
	%	9.1	28.1	62.5	0.3		
High temperatures may add heat stress, lead to rise of pests and diseases hence reduced quality and quantity of tea leaves produced	n	94	44	35	179	2.85	1.298
	%	26.7	12.5	9.9	50.9		

Source: Field data, 2020

In the table 3 above, there was a unanimous agreement that high temperatures cause high transpiration rates leading to reduced yields. It was also evident that high temperatures were responsible for the high evaporation from the soil thus leading to stunted growth, hence reduced yields as was reported by 98% of the respondents. Besides, other effects of temperature on tea production were the notion that high temperatures lead to wilting and drying of tea (89.8%), the assertion that cold conditions damage tea leaves and roots leading to low productivity (27.2%) and the allegation that hot conditions may add heat stress, increase pest infestation and disease prevalence thus reducing both quality and quantity of tea leaves was the least effect temperature. One of the field service coordinators reported the following during the field interviews:

> *Temperature variations has affected tea production negatively. Increase in temperatures has led to high evapotranspiration leading to low yields. Low temperature on the other hand, affect tea leaves leading to reduced yields mostly in the months of June and July.*

The above results support those of Adhikari et al, (2015); Barros et al, (2014) and Vrieling et al., (2013), who found out that water stress caused by increase in temperatures in Africa, increases crop weeds, pests and diseases. In India, it has noted that temperature variability is the most serious factor affecting tea yields in South India (Raj, et al, 2019). A study done in Assam region in India in 2016, revealed that drought increases the susceptibility of tea plant pests (Biggs et al., 2018; Reay 2019).

Indications of Temperature Variations

Temperature variations were indicated by various factors. These were the aspects that the respondents experienced to ascertain that indeed variations in temperature had an effect on tea production. Further, the respondents were sked to give their level of agreement with statements regarding the various indications of temperature variations. The results were as presented in table 4 below.

Table 4: Indications of Temperature Variation

		Strongly agree	Agree	Disagree	Strongly	Mean	Std. Deviati
Switch to drought resistant crops	n	241	79	30	2	1.41	0.669
	%	68.5	22.4	8.5	0.6		
Disappearance/ reduction of water sources/ points due to high evaporation	n	93	253	6	0	1.75	0.470
	%	26.4	71.9	1.7	0.0		
Longest months with high day time temperatures	n	57	116	179	0	2.35	0.743
	%	16.2	33.0	50.9	0.0		
Frost that affects crop leaves	n	36	130	184	2	2.43	0.680
	%	10.2	36.9	52.3	0.6		
Frequent occurrence of heat induced crop pest and diseases	n	55	73	53	171	2.97	1.149
	%	15.6	20.7	15.1	48.6		
Frequent occurrence of heat	n	34	83	69	166	3.04	1.046

induced animal diseases	%	9.7	23.6	19.6	47.2	

Source: Field data, 2020

On the count of indications of temperature variations, results showed majority of the respondent (90.9%) agreed that farmers have shifted to drought resistance crops in order to mitigate the problem of drought. Another major sign of temperature variability was the Disappearance and/or reduction of water sources/ points due to high evaporation as reported by 98.3% of the respondents. Other indicators of variations in temperature were experiencing the longest months with high day time temperatures, presence of frost that affects crop leaves, frequent occurrence of heat induced crop pest and diseases as well as frequent occurrence of heat induced animal diseases as shown in Table 4 above.

These findings support a study done in Sri Lanka which revealed that tea production correlated negatively at higher levels in warmer months and lower temperature in colder months (Nijamdeen et al., 2018), which was due to agricultural droughts and high rate of transpiration. It was also found out that high temperatures increase evaporation losses of soil moisture and accelerate burning of organic matter from soils. This agrees with FAO, (2016b), which has also noted that higher daytime temperatures during the reproductive stage leads to the decline of crop yields. One of the field service coordinators reported the following during the field interviews on pests and diseases:

> *Pests such as aphids, mites and diseases such as armillaria root rot and stem caker are common. Mites appear during the seasons when there is high temperature, dry conditions and absence of shade. Root rot disease usually occurs during the wet season where the soils are poorly drained which leads to death of the tea plants*

The above response agrees with Sawe et al., (2018) who found out that increase in crop pests and diseases are mostly associated with to increase in temperatures. It further supports Adhikari et al, (2015); Barros et al, (2014) and Vrieling et al., (2013), who found out that water stress caused by increase in temperatures in Africa, increases crop weeds, pests and diseases and in n India, (Raj, et al, 2019).

Conclusion

From the results, the study concludes that the perception of the farmers concerning the effects of temperature is that scanty rainfall reduces tea yields, heavy rainfall causes erosion of top soil and washes away available fertilizer thus affecting tea production, and that frostbites reduce tea yields and production significantly since hailstones destroy the tea leaves and reduces tea yields drastically.

Recommendations

In the analysis, severe heat conditions can increase the infestation and prevalence of pests and disease, which decreases both the quality and amount of tea leaves. The study thus indicates that farmers should use integrative methods that are friendly to the environment, such as biological and traditional methods to control them.

Bionote

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